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BOTANICAL GAZETTE

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A CONTRIBUTION TO THE LIFE HISTORY AND CYTOLOGY OF ERYTHRONIUM.

CONTRIBUTIONS FROM THE BOTANICAL LABORATORY, OHIO STATE UNIVERSITY. VIII.

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(WITH PLATES IV–IX)

SEVERAL years ago, while studying at the University of Chicago, the writer made a special investigation of the reduction nucleus in the ovule of *Lilium Philadelphicum*, maintaining that a true reducing division occurs in this plant (**29**). Immediately after the completion of the investigation, search was made for another plant in which to continue the study of reduction, together with other points of interest in the life history. The type finally selected was Erythronium, and both *E. albidum* and *E. Americanum* have been studied. The work was carried on for some time at the University of Chicago, and has been continued for the past three years at the Ohio State University. The material was collected mainly near Chicago and in the vicinity of Columbus, but some was also obtained from Kansas. It is exceedingly difficult to procure the earlier stages of the flower, since bulbs with flower buds are very rare when compared with the numerous younger sterile ones.

The usual methods of killing and staining were used; the killing fluids being chrom-acetic acid and Flemming's weaker fluid; and the stains anilin-safranin and gentian-violet, Heidenhain's iron-alum-hæmatoxylin, Delafield's hæmatoxylin, and

anilin-safranin and picro-nigrosin. The sections were mostly cut 10, 12, and 18 μ, and stained on the slide.

GENERAL CHARACTERS.

The deeply buried bulbs begin to develop the incept of the flower early in the summer. By the first of September the incipient flower bud is considerably advanced, and the carpels are developing the ovules. Usually before the first of October the single hypodermal archesporial cell can be distinguished, and the integuments are just beginning to make their appearance. The anther wall shows five layers and the pollen mother cells are enlarging. By December first the tetrads are formed, but separation of the four microspores may be delayed for some time later in certain flowers. The cells of the anther are filled with starch grains and the tapetum is still active, some of its nuclei being in stages of direct division. At this time there is no sign of the division of the nucleus of the microspore, but the exine of the wall is developing. The nucleus divides some time between December 1 and April 1, but the time was not ascertained. In the meantime, the archesporial cell in the ovule has been increasing in size and activity, and has formed the continuous spirem from the chromatin network. In this condition it passes the winter. The cell in which the reduction takes place, therefore, has a period of development extending over six months. In some years it cannot be much less than eight months. It will also be observed that while the reduction division in the anther takes place in the fall, in the ovule it is delayed until early spring.

The flowers are growing rapidly long before the frost is entirely out of the ground, and during this time the divisions in the embryo sac occur, so that when the flowers come out of the ground the divisions are usually completed.

Very few flowers appear to develop ovules of any size, and ripe seed is very scarce. In fact I have seen very little during the past three years. Propagation is effected largely by means of the multiplication of the bulbs. About the first of June, at

Columbus, most of the leaves have wilted away. The plant, therefore, is rarely much more than two months above ground.

Erythronium is an ideal example of the retreating bulb. The retreating stems are axillary buds which are carried downward by growth and division of the cells above and beside the apex of the bud. *Fig. 1* is a section of such a young bulb, and the dotted region shows where active cell division is going on. The development of these offsets has been described several times recently, so that it is unnecessary to refer to the subject further.

The deep burrowing is probably not only to place the plant in deep soil, but also to keep the flower protected in the warm earth during winter. The advantage of retreat for nine or ten months underground must be decided, and the causes for the habit complex. The leaves come out before there is any danger of shading from other plants, and before the leaves of the higher stratum of trees shut out the light. The plant is thus well adapted to forest conditions.

KARYOKINESIS IN THE BULB.

The division stages in the bulb were studied in order to trace out the development of the spindle. The resting nuclei usually have a rather dense chromatin network with numerous nucleoli imbedded in cavities (*fig. 2*). Often the nucleoli take on fantastic shapes, probably due to budding and division. Some of these are shown in *fig. 3*, *a*, *b*, *c*, etc. Farther up, beyond the division region, the nuclei elongate in the cells of the developing vascular bundles. After the continuous spirem begins to form, two caps of fibers appear on opposite sides of the nucleus, which are the incepts of the future spindle. These are dome-shaped or cone-shaped in appearance, and often end in definite granules around which there is sometimes a system of radiations (*fig. 5*). Similar incipient spindles, but farther advanced, are shown in *figs. 6*, *7*, and *8*. In *fig. 7* the chromatin granules are plainly visible in the spirem, forming a single chain. *Fig. 9* represents a loose mother skein some time before the formation of the mother star. The spindle at this stage is

sharply pointed and ends in small centrosomes. After the daughter star stage there are sometimes two bodies at each pole, which may represent divided centrosomes (*fig. 10*). The cells of the bulb are often packed with starch. In some cases the starch is so abundant that the spindles are very much crowded by it (*figs. 11, 12*). It will be seen from an examination of the figures that the development of the spindle proceeds as in the roots of Allium (**30**) and Pinus (**12**). It is never multipolar. This seems to be the normal course of division in vegetative cells, and represents the way in which the spindle is developed during the normal quantitative karyokinesis in the higher plants.

Some time after the appearance of the *Cytologische Studien*, Němec, studying in the Bonn laboratory, announced that in vegetative cells the spindle is bipolar from the beginning. It is doubtful, however, whether the classification he made of bipolar and polycentric spindles will be found to hold good in general.

THE MALE GAMETOPHYTE.

The nucleus of the microspore probably divides early in the spring, for the pollen grain is well developed before the frost has left the ground. The tube nucleus takes a very light stain and is comparatively small, while the generative nucleus is large and is surrounded by dense-staining cytoplasm which is organized into a cell amoeboid in form (*figs. 16–18*). These generative cells are very striking in appearance. They can hardly have a cellulose wall because of the peculiar shapes they assume. The dense coat of cytoplasm is very different from that of Sagittaria and Alisma, where there is very little cytoplasm, and it is difficult to see anything but the nucleus.

Fig. 19 shows a germinated pollen grain on the stigma. The tube nucleus and generative cell are still side by side in the body of the grain, but are evidently preparing to pass into the tube. In the tip of the tube there is some dark-staining material which becomes very abundant as the tube elongates, forming dark masses or plugs (*fig. 20*). The tips of tubes in very favorable preparations showed no definite nuclei (*fig. 21*). They must be

farther up among the masses of dark-staining material and are thus difficult to identify.

In the liliaceous types the division of the generative nucleus takes place in the tube; in many Helobiae and some other monocotyledons, in the grain before it is shed. In Typha the generative nucleus does not divide in the grain, while in Silphium (**22**), one of the highest types, the division is in the grain and the sperm cells are elongated and even coiled like spermatozoids. Such elongated sperm cells are also common in Alisma. It appears, therefore, that progressive reduction of the male gametophyte has not been uniform in the various lines of angiosperms. Search was made for the division of the tube nucleus, as is common in certain species of Lilium (**8**) and Hemerocallis (**13**), but nothing was found. Such a division probably never occurs in Erythronium.

The style has a large continuous canal, from the stigma to the cavities of the ovulary, for the conduction of the pollen tube. This canal is lined by a layer of glandular cells for the nourishment of the tubes (*figs. 13, 14*). The pollen tube does not grow through any tissue until after it passes into the micropyle. It is not difficult to see how such an angiosperm could develop from a gymnospermous condition.

THE DEVELOPMENT OF THE MEGASPORANGIUM AND THE REDUCTION DIVISION.

As stated before, the archesporial cell begins to enlarge about the first of October, and by December first the chromatin network is very distinct and is being transformed into the continuous spirem (*figs. 22–24*). In the following stages the nucleus becomes very large, and the same is true of the chromosomes. This makes Erythronium a favorable subject for the study of these structures. After December the nucleus probably goes into a partial state of rest until early in the spring, at which time development and division continue. During this period it will be convenient to call the cell a megaspore. The spirem is at first very long and slender and the chromatin granules are

never so prominent as in *Lilium Philadelphicum* (*figs. 25–25a*). In *L. Philadelphicum* the chromatin granules divide and the chromatin band undergoes longitudinal splitting before much shortening and looping take place, but in Erythronium the division of the granules seems to be somewhat later, and they do not appear double until the band has twisted into the twelve loops (*figs. 26, 27, 28, 37*). The granules are large and more or less irregular in shape. A little later the chromosomes appear homogeneous throughout. This would certainly give support to the belief that the division of the chromatin granules is a mechanical contrivance for bringing about the longitudinal division of the linin band, although this might not at all interfere with their supposed function as bearers of hereditary tendencies.

The breaking apart of the twelve loops to form the twelve individual chromosomes (*fig. 29*) appears to be accomplished by the twisting and contracting movements of the band. The chromosomes are usually of various sizes, some being much larger than others. They often appear as single coiled loops (*figs. 37, 38*), but usually their double nature can be readily observed. The chromatin loops are not so closely coiled as in *Lilium Philadelphicum*, and when they are arranged in the mother star the twisted condition can still be distinguished. The chromosomes appear to be attached to the spindle threads near the two free ends of the loop, the closed end extending outward (see *figs. 39–48*, chromosomes before division, and *figs. 49–57*, chromosomes after division). During metakinesis the loops are uncoiled, and the two free ends are gradually pulled apart until each chromosome breaks in the middle, thus accomplishing a transverse division, one end of the original chromatin loop going to the one pole, and the other to the opposite one. This would be a true reducing division. It is exceedingly difficult to follow out the course of events at this point, and there is always room for doubt as to correct interpretation. There is a possibility that the loops are attached at the closed ends. However, some of the examples are quite convincing, and another than a transverse division seems out of the question (see

especially *figs. 46* and *47*, also compare the undivided chromosome, *fig. 44*, with a chromosome in the daughter star, *fig. 57*). There is not a single example which will not agree with the supposition of a transverse division, while many of the figures could not be explained on the supposition of a longitudinal one. And while it may perhaps be granted that a transverse division has not been absolutely established, it may be said that there is much less evidence in favor of a longitudinal one. In the next division the chromosomes are V-shaped and the longitudinal splittings perfectly apparent (*figs. 69, 70*).

Although there is no way known to the writer of tracing the origin of the reduction chromosomes in this nucleus to two previous ones, theoretically one might consider it possible that the reduction chromosome represents two normal chromosomes, and the closed loop the point where the usual transverse break should have taken place. Were this the case, the points of attachment of the spindle fibers at or near the two free ends would represent the heads of the two simple chromosomes, and the break at the head of the loop during metakinesis simply the delayed division bringing about the usual number of pieces. But such a process would necessarily result in a qualitative division.

The process here described is essentially the same as that reported for *Lilium Philadelphicum*, and the interpretation is similar, since it appears to the writer, after a long and careful study of the objects, that no other interpretation seems possible.

On account of the contradictory character of the investigations so far published, it appears that one or the other set of observations has been wrongly interpreted, or else there is more variation in the phenomenon of chromatin reduction than is generally supposed. There may not be so much uniformity in the manner in which reduction is brought about as our present ideas in regard to the nature of chromatin seem to demand; and once the hypothesis is accepted that the chromatin organs are not the only bearers of heredity, there is no reason why a large amount of variation should not be present. There is

still room for entirely new hypotheses, and care should be taken lest newer and perhaps better suppositions be rejected by the too common appeal to authority.

Shortly before the publication of my paper on Lilium, but not until the investigation had been completed, articles on the subject of reduction were published by Calkins (6), Mottier (23), and Strasburger (34). Each of these authors presented evidence favorable to the hypothesis that a transverse splitting of the chromosomes occurs during the reducing divisions of the plants studied. Miss Sargant (27) had also published a paper somewhat earlier, in which some facts were presented favorable to the supposition of a transverse division. Calkins, however, seems to be the only one of these investigators who has not reversed his published opinion. More recently Belajeff (2) has asserted the transverse division, while Stevens (32) holds that in the ferns studied by him both divisions which go to form the spore tetrad are longitudinal. Guignard (14) has lately also published articles on the subject, maintaining that there is only a longitudinal division. Atkinson (1) has published the results of his investigation of sporogenesis in the anthers of *Arisaema triphyllum* and *Trillium grandiflorum*. In the case of Arisaema he states that a qualitative division takes place in the first division, while in Trillium it occurs in the second. Duggar (11) also believes that a transverse division occurs in the first division in *Symplocarpus fœtidus*. In studying the development of the microspores of *Convallaria majalis* and *Potomogeton foliosus*, Wiegand (35) was unable to determine whether the division was longitudinal or transverse, but he inclines to the belief that it is transverse in the second division. Thus it appears to be very doubtful in which division the reduction normally occurs. Here, as in many other problems of cytology, the personal element is still very large.

The zoologists also report these variations. Paulmier (25), in his study of the spermatogenesis of *Anasa tristis*, says that the chromosomes have a twisted appearance, and that the first division is transverse and a true reduction division, while the

second is an equation division. Some zoologists have found that in certain animals the second is the reduction division.

Some of the nuclei of Erythronium are of enormous size. Those in the walls of the ovule are usually from 15 to 20 μ in diameter, while the large reduction nucleus often measures from 40 to 50 μ. In many cases, where the sections were cut 18 μ thick, the spindle was distributed through three sections. In such cases the spindle threads not only have their terminals cut but they are often more or less distorted. The same is true of the nuclei before the spindle is formed. If such a large spindle were cut into sections 5 μ thick it would be distributed through nine or ten sections!

In the sliced spindles of Erythronium multipolar figures are very common. Examples are shown in *figs. 31, 32a, 33, 34,* and *35*. In *fig. 31* one pole is intact and ends in a dark body, while the other is cut off. *Fig. 32a* is a multipolar spindle representing a tangential section. The other part of the spidle is little injured and shows well-developed centrosomes at the poles (*fig. 32*). In *fig. 34*, a strand of spindle threads has been displaced, so that it projects beyond the limits of the cytoplasm. In this material no multipolar spindles were found which were not sectioned, and they are therefore not regarded as being the result either of normal or diseased conditions, but simply due to the method of preparation. Indeed, the nuclei and spindles were so large that it was difficult to obtain the chromosomes in their normal positions, as they were frequently displaced by the knife.

Unfortunately, the stages were not at hand for tracing out the origin of the spindle. *Fig. 28* represents the general appearance of a section of the nucleus some time before the final looping takes place. The nucleus usually has an enlarged or expanded appearance, with the spirem lying free in the cavity. *Fig. 27* shows a large number of false poles produced as the result of contraction. In *fig. 26* the spirem has looped up into the twelve loops, but no sign of a spindle appears either on the inside or outside of the nuclear membrane. The loops have not

broken apart, but were cut by the knife. It is probable that the spindle begins to form rapidly at about this stage, although it might already have passed its incipient stage and not be detected, if it lies closely applied to the nuclear membrane.

In the study of *Lilium Philadelphicum* the writer was unable to discover the origin of the radiations which appear around the daughter nuclei, but subsequent study of Ranunculus demonstrated conclusively that they originate around the poles. *Fig. 56* in Dr. Coulter's article on Ranunculus (**10**) was furnished by the writer as a good example of this. It is from the endosperm of *R. multifidus*, which is a very favorable object for the study of such radiations. In the root tips of *Allium Cepa* the same origin was traced step by step. A comparison of *figs. 30, 32, 36, 58, 59*, and *60* will show conclusively the origin of the remarkable radiations to be seen in well-prepared material of Erythronium. The radiations have their origin from the poles, and only later do the daughter nuclei push outward and give to the radiations an apparent nuclear origin. The radiations at first appear to be very straight and regular (*fig. 36*), while later they become more or less distorted before they begin to disappear (*fig. 60*). In favorable sections centrosomes are visible, as appear in *figs. 31, 32, 36, 58*, and *59*. In the stage represented in *fig. 36*, the attraction sphere appears to form a rather indefinite area from which the radiations arise. As to whether these bodies are built up temporarily or are permanent, the present study gives no information. In either case it is proper to call them centrospheres. At least they are the centers for the spindle threads and polar radiations.

The fate of the nucleolus was not discovered. It is still present at the time of the looped mother skein (*fig. 26*). In later stages, at the beginning of the daughter skein, spherical bodies were seen in the cytoplasm which may be extruded nucleoli (*fig. 59*). No figures were seen in the entire study which could be interpreted as a synapsis stage. The writer has maintained that what is usually called synapsis is a mere artifact which can be produced at will by using proper reagents. At the beginning of the formation of the spirem, however, the chromatin thread

becomes free and continues to orient itself and contract until the looped mother skein is formed. There is a continuous shortening and thickening and often twisting up of the entire spirem, but the contraction is not one-sided, and it does not appear to have any special relation to the nucleolus.

THE SECOND AND SUBSEQUENT DIVISIONS.

The division of the reduction nucleus gives rise to the first two cells of the gametophyte. The daughter nuclei go into a resting stage and form a network from which a new spirem is developed (*figs. 61–63*). The network at first shows granules which are visible in a single chain in the spirem (*fig. 66*), but they are not visible after the mother star is formed (*figs. 68, 69, 70*). The chromosomes are distinctly V- and U-shaped, and the daughter chromosomes are formed in the ordinary way by longitudinal splitting (*figs. 69, 70*). This is a normal quantitative karyokinesis, therefore, which is quite similar to the sporophytic quantitative karyokinesis except that there are only half the number of chromosomes formed by the transverse breaking of the spirem. Several countings indicate about twelve chromosomes in the daughter star. In one case the chromosomes were all distinct and plainly twelve in number.

The spindle in *fig. 68* has been sectioned, and this may account for the lack of poles. The relation of the large vacuoles to the position of the poles of the incipient spindle should also be noted (*figs. 65–67*). There are often remarkable radiations around the mother nucleus. These have nothing to do directly with the formation of the spindle, however, and are the radiations normally present at this stage in both plant and animal karyokinesis. In some cases it appears that they may have their origin at the dome-shaped caps of the spindles (*figs. 63, 64*). There are also numerous strands of the central spindle left between the daughter nuclei of the first division, and it is probable that some of the radiations around the daughter skeins may also be left and be preserved to the beginning of the following division. The third division which gives rise to the

eight-celled embryo sac appears to be of the same nature as the second. *Fig. 71* shows the position of these spindles. The uppermost nucleus gives rise to the two synergids, the one below this to the egg and upper polar nucleus. A typical arrangement of these divisions is shown in *fig. 72*. The old spindle has survived in this instance, and has separated into two limbs below. As is usual in many of the Liliaceae, the egg apparatus is not very definitely organized. A nearly mature sac is represented by *fig. 73*. In this case, however, the nuclei are larger than usual.

Some interesting features were observed in the second division. In some cases the cytoplasmic radiations around the nucleus at the beginning of the formation of the spirem did not extend to the incept of the spindle, but ended in a rather dense cytoplasmic zone surrounding this (*fig. 62*). This of course may not be of any special significance, but merely an individual peculiarity. The fate of the central spindle of the first division, however, deserves special mention. This, as stated, persists usually until the following division is well under way. Then it often appears to mass up into two very dense irregular bodies which stain very deeply (*figs. 65, 66, 68*). Whether these masses represent a special substance distinct from the general cytoplasm and that part of the cytoplasm which alone is used in the formation of spindle threads and radiations it would be difficult, of course, to tell at present. There is little question as to the origin of the masses, and if there is a special substance for the formation of spindle threads and radiations, distinct from the cytoplasm proper, these masses must represent such a substance.

THE DEVELOPMENT OF THE EMBRYO.

No stages of fertilization were discovered, nor any in which the polar nuclei were conjugating. When the pollen tube enters the micropyle it increases enormously in size and is exceedingly distinct. It is very different in appearance from the tubes in Alisma and Sagittaria. The definitive nucleus begins to divide about the time of the union of the male

and female gametes. *Fig. 74* shows an embryo sac with the three antipodals, the dividing definitive nucleus, the oospore, two synergids, with an extra nucleus which may be a sperm cell, and a nucleus in the pollen tube, probably the tube nucleus. During the first few divisions of the embryo, the formation of the endosperm proceeds very rapidly (*fig. 76*). The oospore divides first by a transverse wall (*figs. 75, 76*), and then each resulting cell divides by a vertical wall, forming a four-celled embryo (*figs. 77, 78*). These divisions are almost simultaneous, although the upper one usually leads. Sometimes, however, the divisions are more irregular (*fig. 81*).

The young embryo lies free in the endosperm some distance from the upper end of the sac, and the synergids disappear very early. After the first few divisions of the embryo the sac enlarges greatly below, while the upper part remains narrow and may even contract (*figs. 76, 77, 79*). *Fig. 79* represents a five-celled embryo, one cell being cut from the upper tier and one from the lower. *Fig. 80* is a six-celled embryo in which the two lower cells have each divided by a transverse wall, while *fig. 81* represents a six-celled embryo with two cells of the lowest tier cut away. *Fig. 82* is a twelve- to fifteen-celled embryo, and *fig. 83* about a twelve-celled one. These examples will show how very irregularly the development proceeds. Up to this time and later there is usually a distinct difference between the cells which came from the upper and lower cells of the first division. This difference is shown not only by a difference in the contents of the cell, but especially by the staining reaction. Thus in *fig. 83* the upper or suspensor cells have a bright yellowish cytoplasm, while the embryo cells are very granular and deep red. This is also present in *Lilium Philadelphicum*, sometimes being very prominent in the older embryos (9). *Figs. 84* and *85* represent later stages of the embryo of *E. albidum*. The suspensor region is rather large and often very irregular in shape and much lobed, but the whole structure gives rise to only a single embryo, as was verified by numerous examples. The embryos were very badly shrunken, however,

because imbedded in the horny endosperm which is not easily penetrated by killing fluids. In *E. Americanum*, as shown by Jeffrey, the suspensor is much larger. *Figs. 87* and *88* represent sections of two embryos from this plant. These show well the large umbrella-like suspensor. The lowermost lobe is the one which develops the embryo, but if any of the other lobes of the suspensor should become separated from the main mass it would probably develop an independent embryo. This would be only an accidental case, however, as may frequently happen in any embryonic tissue. This is probably not to be regarded, therefore, as an ordinary case of polyembryony, but the large suspensor is especially developed as an embryonic absorbent organ, as suggested by Coulter (**9**).

COLUMBUS, OHIO.

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EXPLANATION OF PLATES IV–IX.

The figures are reduced to three eighths of their original size. All the figures not especially indicated are from *Erythronium albidum*. The combination of objective and ocular is given for each case, the following being used: Zeiss compensating oculars, 4, 6, 12, 18; Zeiss 8.0^{mm} apochromatic objective; Leitz $\frac{1}{16}$ oil immersion and 1 objective; Leitz ocular 8; Bausch and Lomb $\frac{1}{12}$ oil immersion and $\frac{2}{3}$ objectives. The drawings were made with the aid of an Abbé camera lucida.

FIG. 1. Section of young bulb showing region of cell division dotted. L. 1 Z. 6.

FIG. 2. Normal resting nucleus in growing tip of bulb. B. & L. $\frac{1}{12}$ Z. 12.

FIG. 3. *a*, *b*, *c*, etc. Nucleoli of various shapes from nuclei in growing bulb. B. & L. $\frac{1}{12}$ Z. 12.

FIG. 4. Elongating nucleus in region of developing vascular bundle. B. & L. $\frac{1}{12}$ Z. 12.

FIG. 5. Close mother skein with incipient spindle, from young bulb; fuchsin iodin-green. B. & L. $\frac{1}{12}$ Z. 12.

FIG. 6. Dome-shaped spindle from bulb with granular areas at the tips of the domes; anilin-safranin gentian-violet. B. & L. $\frac{1}{12}$ Z. 4.

FIG. 7. Dome-shaped spindle with centrospheres, from bulb; chromatin granules distinct; early close mother skein; anilin-safranin gentian-violet. B. & L. $\frac{1}{12}$ Z. 12.

FIG. 8. Early close mother skein with dome-shaped spindle, from bulb; anilin-safranin gentian-violet. B. & L. $\frac{1}{12}$ Z. 12.

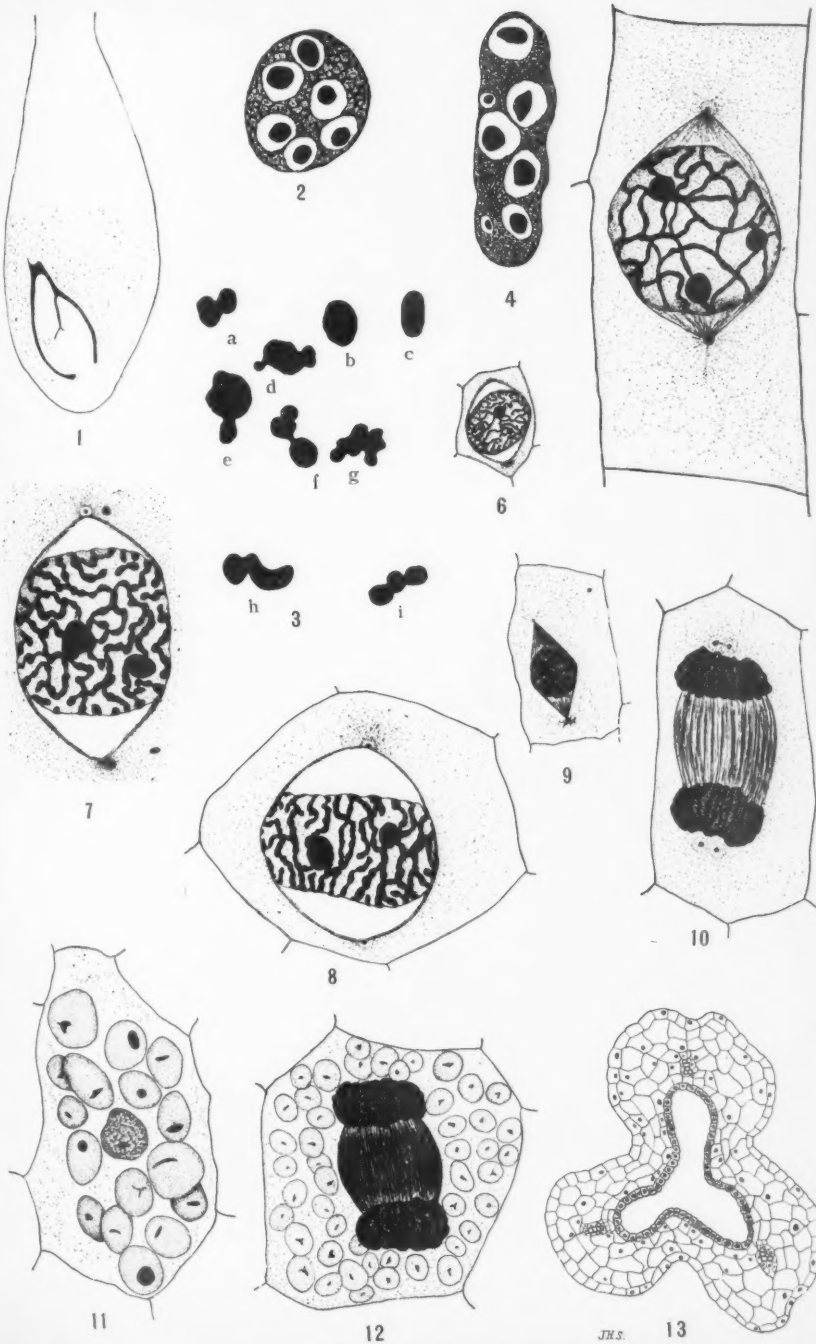
FIG. 9. Beginning of looped mother skein with bipolar spindle and centrosomes, from bulb; anilin-safranin gentian-violet. B. & L. $\frac{1}{12}$ Z. 4.

FIG. 10. Spindle with centrospheres from nucellus; anilin-safranin gentian-violet. L. $\frac{1}{16}$ Z. 12.

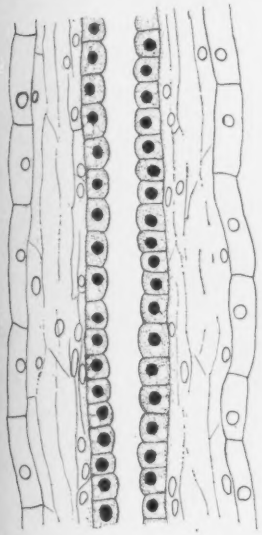
FIG. 11. Cell with starch, from bulb. B. & L. $\frac{1}{12}$ Z. 4.

FIG. 12. Dividing cell, packed with starch, from bulb. B. & L. $\frac{1}{12}$ Z. 12.

FIG. 13. Cross section of style showing glandular cells lining the style canal. B. & L. $\frac{2}{3}$ Z. 4.



SCHAFFNER on ERYTHRONIUM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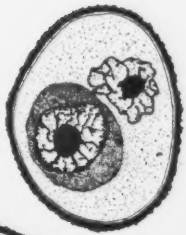
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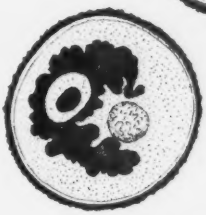
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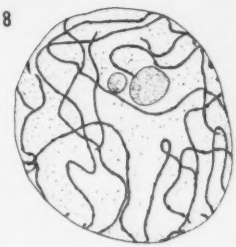
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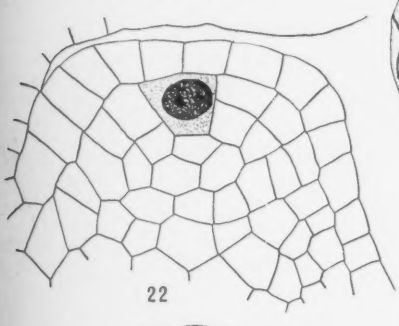
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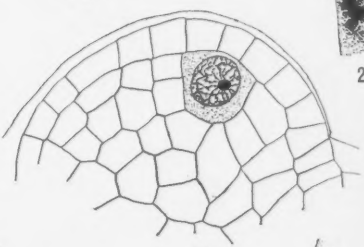
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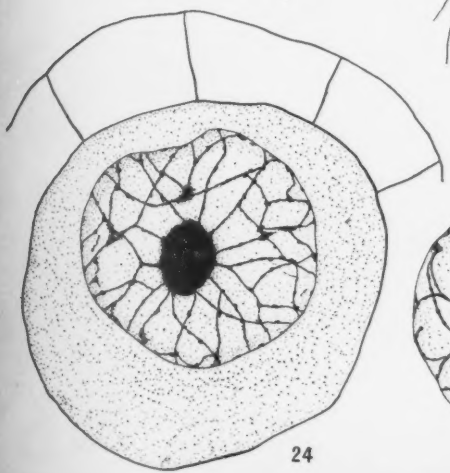
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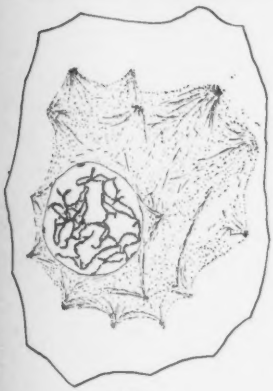
SCHAFFNER on ERYTHRONIUM



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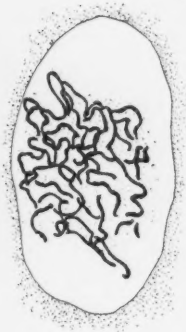

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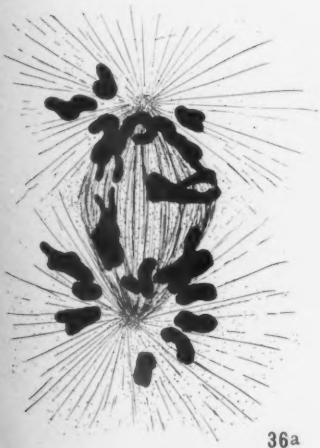

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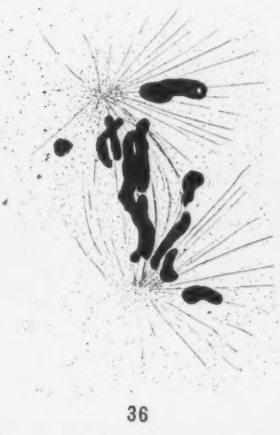

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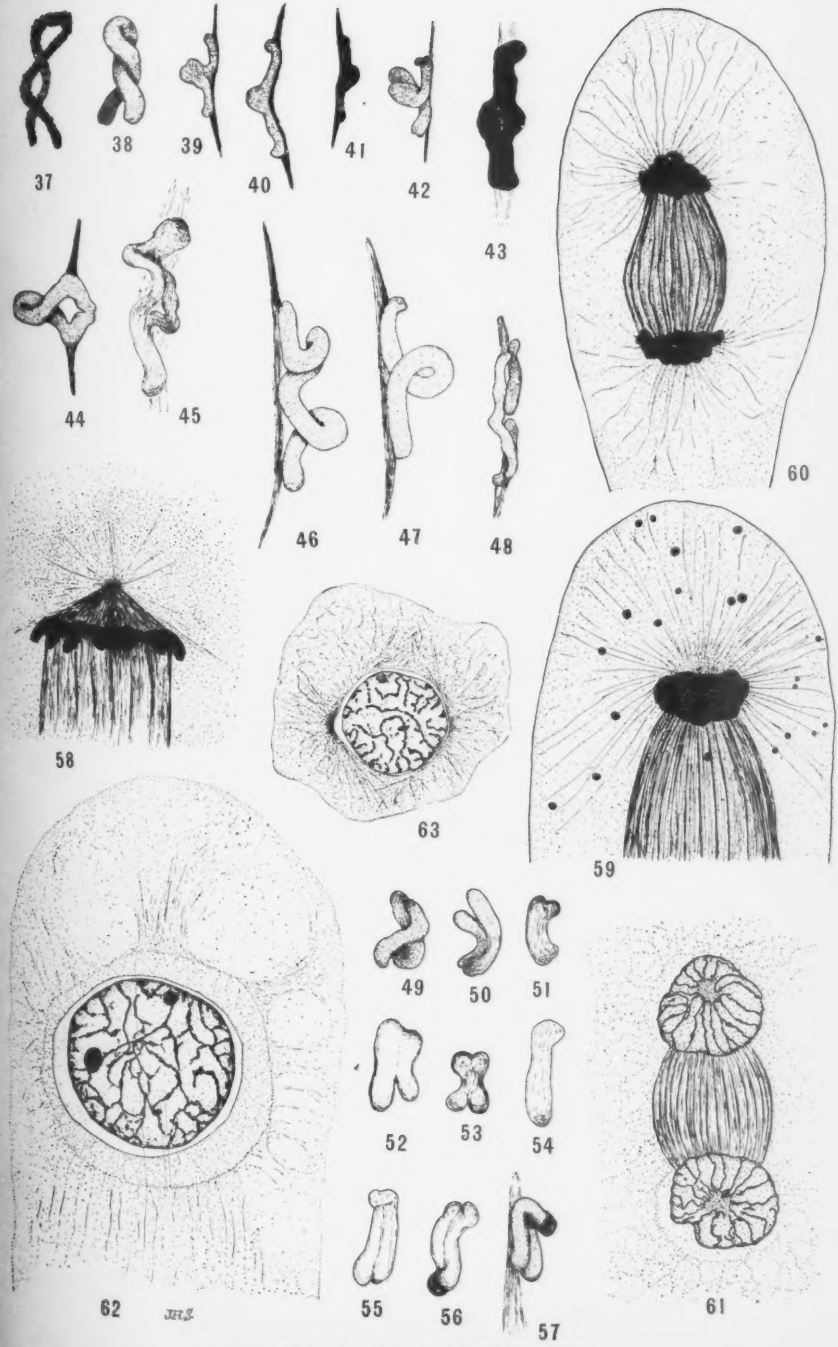
SCHAFFNER on ERYTHRONIUM



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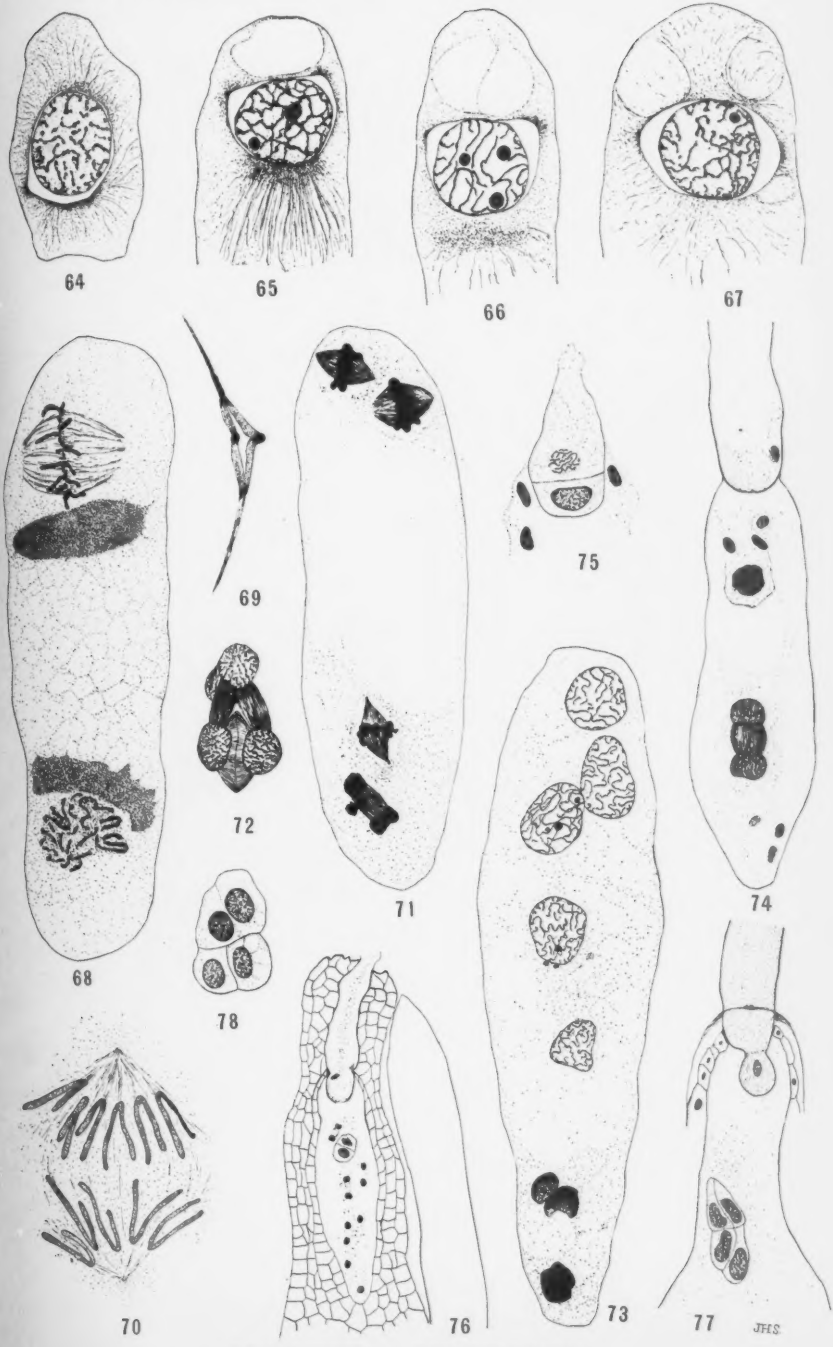

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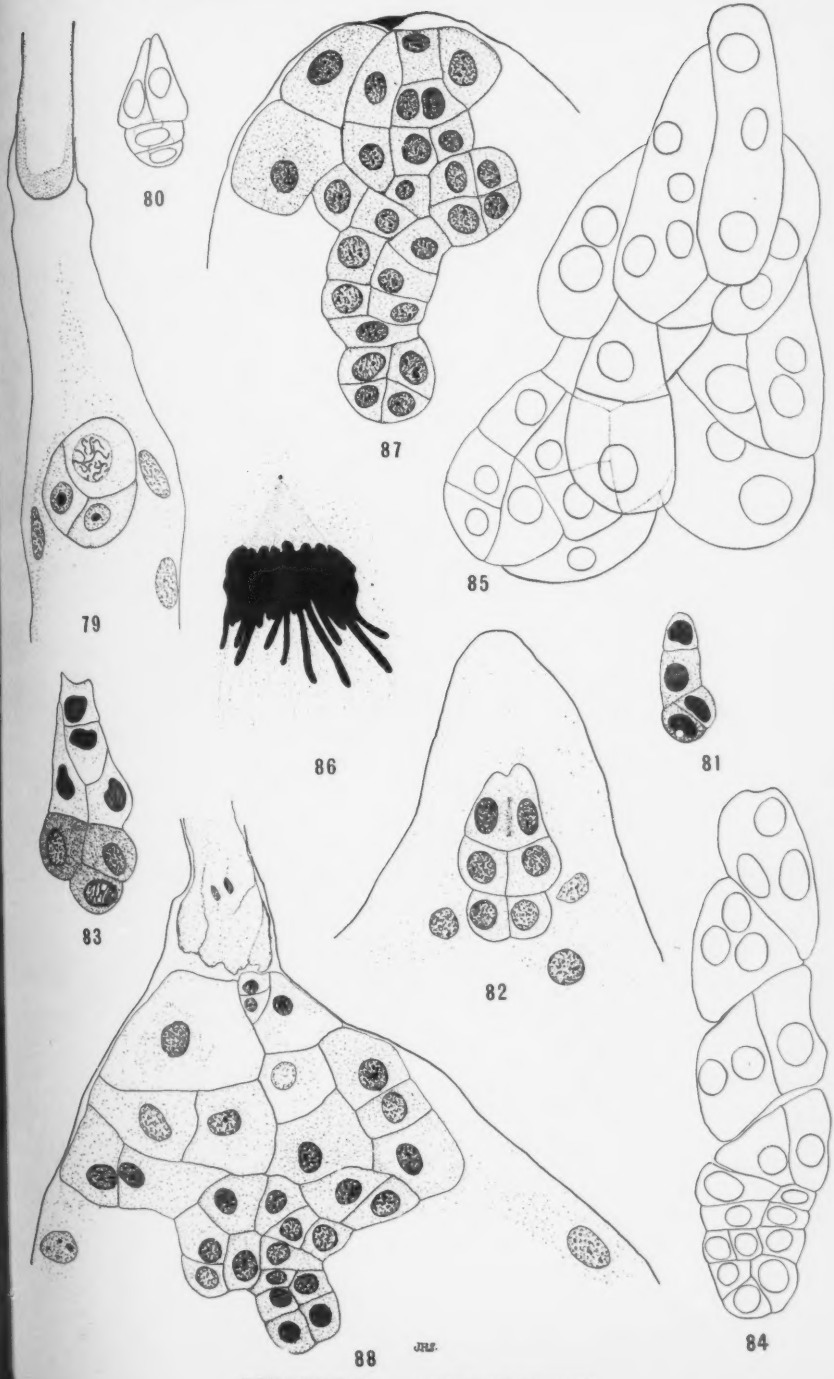

SCHAFFNER on ERYTHRONIUM

FIG. 14. Longitudinal section of style showing glandular cells. B. & L. $\frac{1}{2}$ Z. 18.

FIG. 15. Microspore of *E. Americanum*, December 1. L. $\frac{1}{16}$ Z. 4.

FIG. 16. Pollen grain of *E. Americanum*, April 15; anilin-safranin picronigrosin. L. $\frac{1}{16}$ Z. 4.

FIG. 17. Pollen grain; anilin-safranin gentian-violet. L. $\frac{1}{16}$ Z. 4.

FIG 18. Pollen grain; anilin-safranin gentian-violet. L. $\frac{1}{16}$ Z. 4.

FIG. 19. Pollen grain on stigma with short pollen tube; anilin-safranin gentian-violet. B. & L. $\frac{1}{12}$ Z 4.

FIG. 20. Pollen tube in the style canal showing plugs of dark-staining material. B. & L. $\frac{1}{12}$ L. 8.

FIG. 21. Tip of pollen tube. B. & L. $\frac{1}{12}$ L. 8.

FIG. 22. Young ovule of *E. Americanum* with archesporial cell, October 1. Z. 8 Z. 18.

FIG. 23. Young ovule of *E. Americanum* with archesporial cell, December 1. Flemming's triple stain. Z. 8 Z. 18.

FIG. 24. Young ovule of *E. Americanum* with archesporial cell developed directly into a megaspore, December 1; network beginning to form the continuous spirem; anilin-safranin gentian-violet. L. $\frac{1}{16}$ Z. 12.

FIG. 25. Megaspore nucleus in April; continuous spirem and pale-staining nucleolus; anilin-safranin gentian-violet. L. $\frac{1}{16}$ Z. 12.

FIG. 25 *a*. Another section of the same.

FIG. 26. Megaspore nucleus in looped mother skein stage; anilin-safranin gentian-violet. L. $\frac{1}{16}$ Z. 4.

FIG. 27. Megaspore showing effect of contraction; may be due to freezing; anilin-safranin gentian violet. L. $\frac{1}{16}$ Z. 6.

FIG. 28. Megaspore nucleus at close of close mother skein stage. L. $\frac{1}{16}$ L. 8.

FIG. 29. Megaspore showing twelve chromosomes after disappearance of nuclear membrane. L. $\frac{1}{16}$ Z. 4.

FIG. 30. Megaspore spindle with peculiar poles; anilin-safranin gentian-violet, iron-haematoxylin. L. $\frac{1}{16}$ L. 8.

FIG. 31. Megaspore spindle with one pole cut away and a centrosome at the other; the other pole was in the following section; anilin-safranin gentian-violet, iron haematoxylin. L. $\frac{1}{16}$ Z. 12.

FIG. 32. Megaspore spindle cut 18 μ thick; distinct centrospheres at the poles; anilin-safranin gentian-violet. L. $\frac{1}{16}$ Z. 6.

FIG. 32 *a*. The following section of the same spindle showing multipolar spindle because of longitudinal sectioning.

FIG. 33. Megaspore; multipolar spindle produced by diagonal cut; several of the chromosomes disturbed by the knife and some in following section; anilin-safranin gentian-violet, iron-haematoxylin. L. $\frac{1}{16}$ Z. 6.

FIG. 34. Another multipolar spindle produced by diagonal cut; one set

of spindle threads dragged out by the knife; anilin-safranin gentian-violet, iron-haematoxylin. L. $\frac{1}{16}$ Z. 6.

FIG. 35. Spindle sectioned near the middle; part of one pole remaining; anilin-safranin gentian-violet. L. $\frac{1}{16}$ Z. 12.

FIG. 36. Daughter star stage showing remarkable radiations around the poles; anilin-safranin-gentian-violet. L. $\frac{1}{16}$ Z. 12.

FIG. 36*a*. Another section of the same.

FIG. 37. Chromosome from reduction nucleus showing twisted condition and late transverse division of chromatin granules; loose mother skein; anilin-safranin gentian-violet. L. $\frac{1}{16}$ Z. 12.

FIG. 38. Mature typical chromosome; chromatin granules have disappeared; anilin-safranin gentian-violet. L. $\frac{1}{16}$ Z. 12.

FIGS. 39–42. Chromosomes at beginning of metakinesis, showing method of untwisting; anilin-safranin gentian-violet. L. $\frac{1}{16}$ Z. 12.

FIG. 43–47. Chromosomes in metakinesis stage showing method of untwisting and indicating transverse division; anilin-safranin gentian violet, iron-haematoxylin. L. $\frac{1}{16}$ Z. 18.

FIG. 48. Single chromosome showing apparent transverse division and tetrad character of the twisted chromosome; anilin-safranin gentian-violet. L. $\frac{1}{16}$ Z. 12.

FIGS. 49–57. Half chromosomes after division in early daughter star; the pole end is in each case at the top; anilin-safranin gentian-violet, iron-haematoxylin. L. $\frac{1}{16}$ Z. 18. Compare *figs. 57* and *44*.

FIG. 58. Daughter star in megaspore; two centrospheres at the poles from which extend a series of polar radiations; anilin-safranin gentian-violet. L. $\frac{1}{16}$ Z. 12.

FIG. 59. Daughter skein showing further development of radiations from the pole; dark bodies are probably micronucleoli; anilin-safranin gentian-violet. L. $\frac{1}{16}$ L. 8.

FIG. 60. Daughter skein showing final arrangement of polar radiations; anilin-safranin gentian-violet. L. $\frac{1}{16}$ L. 8.

FIG. 61. Close daughter skein showing disappearance of radiations and beginning of fusion of chromosomes to form the network; anilin-safranin gentian-violet. L. $\frac{1}{16}$ L. 8.

FIG. 62. Upper nucleus in a two-celled embryo-sac; beginning of division; remains of central spindle still prominent; anilin-safranin gentian-violet, iron-haematoxylin. L. $\frac{1}{16}$ Z. 12.

FIG. 63. Upper nucleus of two-celled sac, showing radiations probably coming from two poles; anilin-safranin gentian-violet, iron-haematoxylin. L. $\frac{1}{16}$ Z. 6.

FIG. 64. Lower nucleus of the same sac; the sections are diagonal.

FIG. 65. Upper nucleus of two-celled sac; incept of spindle and remains of central spindle; anilin-safranin gentian-violet, iron-haematoxylin. L. $\frac{1}{16}$ Z. 6.

FIG. 66. Beginning of second division, showing incept of dome-shaped spindle; also beginning of the collection of central spindle material; anilin-safranin gentian-violet, iron-haematoxylin. L. $\frac{1}{16}$ Z. 6.

FIG. 67. Upper nucleus of two-celled embryo-sac, showing incipient spindle; anilin-safranin gentian-violet, iron-haematoxylin. L. $\frac{1}{16}$ Z. 6.

FIG. 68. Section of two-celled embryo-sac showing two peculiar bodies probably formed from the remains of the central spindle; anilin-safranin gentian-violet, iron-haematoxylin. L. $\frac{1}{16}$ Z. 6.

FIG. 69. Chromosome from metakinesis stage of the second division showing longitudinal splitting; anilin-safranin gentian-violet. L. $\frac{1}{16}$ Z. 12.

FIG. 70. Upper spindle of second division showing the characteristic V-shaped daughter chromosomes; anilin-safranin gentian-violet. L. $\frac{1}{16}$ Z. 12.

FIG. 71. Embryo sac showing the third division; anilin-safranin gentian-violet. L. $\frac{1}{16}$ Z. 4.

FIG. 72. Upper two spindles of the third division; anilin-safranin gentian-violet. L. $\frac{1}{16}$ Z. 4.

FIG. 73. Mature but somewhat abnormal embryo sac; Delafield's haematoxylin-erythrosin. L. $\frac{1}{16}$ Z. 4.

FIG. 74. Embryo sac with fertilized egg and dividing definitive nucleus; anilin-safranin gentian-violet. Z. 8 Z. 12.

FIG. 75. Two-celled embryo. Z. 8 Z. 12.

FIG. 76. Two-celled embryo and dividing endosperm; pollen tube in the micropyle. Z. 8 Z. 4.

FIG. 77. Four-celled embryo; pollen tube above. Z. 8 Z. 12.

FIG. 78. Four-celled embryo. Z. 8 Z. 12.

FIG. 79. Section of five-celled embryo; two cells in upper tier and three below. Z. 8 Z. 12.

FIG. 80. Six-celled embryo. Z. 8 Z. 12.

FIG. 81. Six-celled embryo; two cells in the lowest tier cut away. Z. 8 Z. 12.

FIG. 82. Section of twelve to fifteen-celled embryo. Z. 8 Z. 12.

FIG. 83. Section of about twelve-celled embryo, showing marked difference in staining reaction between the upper and lower cells. Z. 8 Z. 12.

FIG. 84. Embryo considerably advanced, showing the large suspensor. Z. 8 Z. 12.

FIG. 85. Restored embryo showing much lobed suspensor about the same age as the preceding embryo. Z. 8 Z. 12.

FIG. 86. Daughter star from endosperm showing sharp pointed spindle ending in a centrosome; anilin-safranin gentian-violet, iron-haematoxylin; *E. Americanum*. L. $\frac{1}{16}$ Z. 12.

FIG. 87. Section of advanced embryo showing lobed suspensor. Z. 8 Z. 12.

FIG. 88. Section of embryo somewhat older than the preceding, showing the massive suspensor; remains of pollen tube in the micropyle. Z. 8 Z. 12.

STUDIES ON CALIFORNIAN PLANTS. I.[1]

H. M. HALL.

(WITH PLATE X)

SPECIES FROM SOUTHERN CALIFORNIA.

Frasera neglecta, n. sp.—Plant perennial, 3–6^{dm} high, with several slender terete glabrous stems arising from a single perpendicular tap root: leaves all opposite, thick and leathery, not at all succulent; the lowermost crowded, 13–18^{cm} long, 4.3–8.6^{mm} wide, interspersed with others only 5^{cm} or less long, tapering for nearly their whole length to the base which abruptly widens and unites with the opposite leaf to form a short sheath; the upper merely sessile by a broad base, those of the inflorescence gradually reduced to spreading or recurved linear-lanceolate acute bracts: inflorescence an elongated interrupted thrysus, the lower cymes on ascending peduncles 5–10^{cm} long, few-flowered, upper cymes short-peduncled or sessile and more densely flowered; pedicels varying from 1^{cm} in length to almost obsolete: sepals 4, lanceolate, cuspidate-acuminate, 6.5^{mm} long, the margins scarious: petals oblong, acute, 8.6–10.8^{mm} long, greenish-white, the veins purple; petaline gland replaced by a tubular nectary, which reaches from the base of the petal nearly to the middle where it appears on the inner surface as a circular cavity with an indenture on the upper side, the orifice surrounded by a raised membrane with finely divided margin forming a fringed border: stamens 4; filaments nearly as long as the petals, tapering from the broad base to the tip; anthers oval: ovary ovate, attenuate into the slender style which is as long as the stamens.

Collected at the head of Swarthout cañon, San Antonio mountains, altitude 2070^{m}, June 1900, 1495 *Hall* (type); Holcomb valley, San Bernardino mountains, August 1882, *Parish;* Rock creek, San Gabriel mountains, July

[1] Contributions from the Botanical Laboratories of the University of California.

1893, *Davidson*. All these localities are on the north slope of the San Bernardino range. The specimens from Holcomb valley are not as thrifty as the type; the flowers are somewhat smaller and the leaves (all under 7^{cm}) are principally from the base, leaving the long internodes exposed. The type is in the Herbarium of the University of California.

This plant has been confused with *Frasera nitida* Benth., but it differs from that more northern species in the more open inflorescence, the more slender and acuminate leaves and bracts, and above all by the absence of the petaline gland, which in *F. nitida* is narrowly oblong and open for its whole length. The nectary in the proposed species is a pocket-like organ inserted within the tissues of the lower part of the petal, the opening surrounded by a narrow flap with ciliate margin. The raised tissues over the lower part of the nectary are ordinarily brown in color.

EXPLANATION OF PLATE X.—*Fig. 1*. A plant from a single root; × ½. *Fig. 2*, a flower; × 1. *Fig. 3*, petal showing nectary; × 2. *Fig. 4*, longitudinal section through petal and nectary; × 2. *Fig. 5*, a stamen; × 2.

ASCLEPIAS CALIFORNICA Greene, Erythea 1: 92. *Acerates tomentosa* Torr. Two well-marked forms of this species are found in Southern California. In the more common form the leaves are broadly ovate and distinctly petioled, while the pedicels are short. The extreme of this form comes from Lytle creek cañon, altitude 1830^{m}, and has leaves 5–6.2^{cm} wide by 7.6^{cm} long, while the pedicels are all under 2^{cm} in length.

The second form has oblong-lanceolate slenderly acuminate sessile leaves and elongated pedicels. The extreme of this form was collected along the Temecula river and has leaves 5^{cm} wide by 15^{cm} long, while the spreading pedicels are 3^{cm} in length.

That these forms do not deserve even varietal rank is shown by the fact that many intermediate forms exist, and one may pass from one extreme to the other by merely ascending a few thousand meters on some of the mountain slopes. At 914 meters in Cajon pass the slender-leaved form prevails, while in passing up the mountains west of the pass various forms are encountered until the extreme of the broad-leaved form is met at 1830 meters.

Gilia modesta, n. sp.—Plant annual, 15^{cm} high or less, divaricately branching from near the base, the branches ascending, either glabrous or sparingly pubescent: leaves mostly opposite below, the upper alternate, 1^{cm} long, palmately 3–7-divided

nearly to the base into rigid linear pungent-tipped lobes, these with strong midribs: flowers disposed singly or in pairs in the forks where they are short pedicellate, and clustered at the ends of the branches where they may be either sessile or short pediceled: bracts similar to the leaves but lobes usually only three, sparingly beset with loose cobwebby hairs: calyx pubescent, 8–11^{mm} long, about equaling the bracts, cylindrical with acute base, hyaline membranous with green ribs prolonged beyond the hyaline portion into pungent-tipped nearly equal lobes which are 2^{mm} or so long: corolla white, with the tube and throat yellow and with two purple lines at the base of each lobe; tube short; throat funnelform, 6–8^{mm} long, nearly equaled by the broadly obovate spreading lobes: stamens equally inserted near the base of the corolla tube, unequal in length, included: ovules in each cell 2 or 3; seeds oblong, developing spiracles only sparingly when wetted.

Gravelly hillsides of Lytle creek cañon along the trail to San Antonio peak, altitude 1830^{m}, June 1, 1900, 1443 *Hall* (type); Swarthout cañon, San Antonio mountains, altitude 2000^{m}, June 3, 1900; near Bear valley, San Bernardino mountains, altitude 2000^{m}, July 16, 1899. The type is in the Herbarium of the University of California.

This species is most nearly related to *Gilia demissa* Gray, but is easily distinguished from that by a number of important characters. *G. modesta* is a much larger plant, with a corolla fully 13^{mm} long, and nearly as wide when expanded, while *G. demissa* has a corolla only 6.5^{mm} long. The proposed species has a calyx of 5 narrow green ribs of equal width throughout, between which is stretched a hyaline membrane connecting them for three fourths their length, while *G. demissa* has a calyx of 5 lanceolate nearly distinct segments each with a scarious margin. The lobes of the leaves and bracts are more slender and rigid than in *G. demissa*, and the ovules are never more than three in each cell, as against seven in *G. demissa*. From *G. Parryæ* Gray it differs in many respects, principally in the absence of scales at the base of the corolla lobes. The general appearance suggests relationship with the members of the Linanthus section, but it differs from all those in the pubescence, in the funnelform corolla, in the small number of ovules, and in other characters.

COLLINSIA CALLOSA Parish, Erythea 7:96, Richardson's ranch near Manzana in Antelope valley, May 1896, 2503 *J. Burtt Davy*. This was probably the first collection of this rare plant, the

original description being drawn from specimens collected in the San Antonio mountains, June 1899.

CHÆNACTIS XANTIANA Gray. This species is well distributed along the mountains surrounding the western part of the Mohave desert, often at altitudes of 1800–2000^{m}. An exceedingly robust form has been collected at Manzana in Antelope valley, altitude 780^{m}, by *Mr. J. Burtt Davy* (no. 1512, May 1896). The stout fistulous stems are 3^{dm} high and terminated by heads 2^{cm} high; involucral bracts slenderly acuminate, 2^{cm} long; the inner pappus when fully developed longer than the corolla. It is hoped that collectors visiting that region may secure more material in order that the relation between this and the typical form may be more clearly understood.

CHÆNACTIS HETEROCARPHA CURTA Gray. Near Estrella in the Coast ranges of San Luis Obispo county, *L. Jared*. In these specimens the paleae of the pappus are reduced to mere rounded scales, which form a crown about the summit of the akene.

A TRIP TO THE SOUTHERN HIGH SIERRAS.

During the summer of 1900 Mr. H. P. Chandler and the writer spent some two months botanizing in the Sierras of Fresno county. Our first stop was at Ockenden, a small settlement on the ridge between the Kings and San Joaquin rivers, and well within the coniferous forests. Reaching here on June 12 we found the season just opening, many of the species still being in too young a condition to make good herbarium specimens.

After spending two weeks in that region we followed the trail to Tehipite valley, making side trips to the Dinkey grove of big trees and Bald mountain *en route*. Tehipite valley is a deep gorge several miles wide on the Middle fork of the Kings river. The floor of the valley is 1220^{m} in altitude, while the walls rise to over 2100^{m}. The flora was somewhat similar to that of the foothill region, and when we reached the valley (July 6) many of the annuals had already passed out of flower.

The Mount Goddard region was also visited, the route leading by Black mountain, Blaney meadows, and the South fork of

the San Joaquin. On July 24 we camped at the very base of the mountain just above timber line. The only shrub seen here was *Salix glauca villosa*, but hardy thick-rooted perennials grew abundantly around the lakes, and fifty-seven species were gathered above 3350^{m}. Thirty-three of these were also found below timber line, leaving twenty-four strictly alpine species. Ascending the peak the vegetation grew more and more scanty, until at 4000^{m} only *Draba Brewerí*, *Erigeron compositus*, and *Polemonium confertum* remained, while on the very summit, at 4130^{m}, the Polemonium was the sole representative of the whole series of phænogamous plants.

The following species collected on this trip seem worthy of note.

~~Erigeron~~ Eriogonum BLOOMERI Parish, Erythea **6**: 87. Not rare in Tehipite valley, July 7, *Hall & Chandler*, no. 513. Determined by Mr. S. B. Parish.

ERIOGONUM NUDUM Dougl. An alpine form was collected near Mount Goddard at 3100^{m}. The slender stems are not over 2^{dm} high and are nearly always simple and monocephalous, July 1900, *Hall & Chandler*, no. 662.

AQUILEGIA PUBESCENS Coville, Contrib. U. S. Nat. Herb. **4**: 56. Among rocks on Mount Goddard at 3660^{m}, July 1900, *Hall & Chandler*, no. 671.

DODECATHEON JEFFREYI **redolens**, n. var.—Exceedingly robust, 4.5–6 ^{dm} high, the herbage redolent with a strong odor: leaves erect, lanceolate or spatulate, 2.5–4^{dm} long including the slender winged petiole: inflorescence glandular pubescent: flowers invariably 5-merous: lower part of stamens and capsule included in the corolla tube, which is not closely reflexed.

Along the lakes at the base of Mt. Goddard, 3400^{m}, July 25, 1900, *Hall & Chandler*, no. 676. Type in the Herbarium of the University of California.

This variety is easily distinguished in the field by the rank odor and by the shape of the corolla. The folding of the latter takes place well up on the tube, thus making the yellow band very prominent, while the purple ring at the base of the corolla in the species is lacking in the variety.

ERIGERON SALSUGINOSUS Gray. This plant, not rare at middle

HALL on FRASERA NEGLECTA, n. sp.

altitudes in the Sierras of Fresno county, exhibits a wide variation in the pubescence. Some specimens are covered with a close pubescence on the leaves and stems, while other are entirely glabrous except on the peduncles and involucres. These forms grow side by side and intergradations are plentiful.

CNICUS TROGANUS Congdon, Erythea **7**: 186. Blaney meadows on the South fork of the San Joaquin at 2320^{m} altitude, July 1900, *Hall & Chandler*, no. 721.

PHALACROSERIS BOLANDERI **coronata**, n. var.—Akenes with an evident pappus consisting of a crown with a divided margin. Otherwise as in the type.

Pine ridge, in the Sierras of Fresno county, altitude 1650^{m}, June 15–25, 1900, *Hall & Chandler*, no. 187 (type). Specimens were also examined from Mariposa county (*Congdon*, October 1896), Yosemite (*Mrs. Brandegee*, July 1883), and Fresno county (*Mrs. Peckinpah*, 1890), and in each case the akenes were found to bear pappus. In old akenes the pappus is not so evident as in the younger ones, as it is curved inward, due to its inability to keep pace with the growing akene. The type is in the Herbarium of the University of California.

The preparation of this paper has been greatly facilitated by the kindness of Miss Alice Eastwood of the California Academy of Sciences, Mr. and Mrs. T. S. Brandegee of San Diego, and Mr. S. B. Parish of San Bernardino, in sending specimens for examination; and of Mr. Merritt L. Fernald, of the Gray Herbarium, for notes on the type specimen of *Gilia demissa*. To Professor W. L. Jepson, of the University of California, I am under special obligations for his continued interest and valuable suggestions without which the paper would not have been prepared.

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CONTRIBUTIONS FROM THE ROCKY MOUNTAIN HERBARIUM. II.

AVEN NELSON.

SOME COLORADO SPECIES.

AN interesting collection of Colorado plants, some 300 numbers, was kindly submitted to me for examination by Professor Ramaley, of the University of Colorado. They were largely of his own collecting, but some of them were by F. Y. Moseley, and yet others by Jennie M. Archibald, of Berwind, Colorado. Among them were many of much interest and a few novelties, upon which the following notes and characterizations are offered.

ZYGADENUS COLORADOENSIS Rydb. This interesting recently described ally of *Z. elegans* seems to be peculiarly a Colorado species, as I have not yet met with it in Wyoming.

CHEIRANTHUS sp. A peculiarly branched form, with petals almost rose-colored, was represented by two numbers. It was evidently not far from *C. asper* Nutt., but fruiting specimens may show it to be distinct.

CLEMATIS SCOTTII Porter. This rare plant was represented by rather young specimens, but even these indicated the distinctness of the species as compared with *C. hirsutissima* Pursh.

SAXIFRAGA RHOMBOIDEA **austrina**, n. var.—Size, habitat and foliage of the species: stems not rarely several from the short rootstock, pubescent with gland-tipped hairs as is also the inflorescence: inflorescence paniculately cymose, strict: calyx lobes obtuse, as long as the adnate base: petals elliptic, white, 3^{mm} long: carpels ovoid, the tips at length widely divaricate: seeds very numerous, brown, oblong, more or less subacute at both ends.

That this is a good species seems quite possible. The paniculate inflorescence and conspicuously gland-tipped pubescence is in strong contast to the usually spherical terminal cluster (which at most becomes only branched-thyrsiform) and the glandless pubescence of *S. rhomboidea* Greene, Pitt.

3:343. In the variety proposed the petals are not emarginate, the calyx lobes are longer than in the species; the presence of a rather conspicuous ciliate-pubescence on the margins of the leaf in the variety adds another point of contrast.

Excellent specimens are in hand from *Jennie M. Archibald*, Berwind, Colorado, 1900, no. 236.

Parosela Porteri, n. sp. — Caudex woody, with a deep-set woody root: stems numerous from the enlarged crown, prostrate-assurgent, quite unequal in length, 10–25^{cm} long (including the oblong spike), strigose, appressed-pubescent: leaves trifoliate, densely appressed strigose-silky, cuneately obovate or narrower, mostly obtuse, 8–14^{mm} long, the terminal one longer than the lateral pair, barely petiolulate, generally shorter than the slender petiole; stipules slenderly and stiffly setaceous, 5–6^{mm} long: spike dense, 2–5^{cm} long; bracts purple, lanceolate-acuminate, equaling or shorter than the calyx, silky-villous; calyx tube campanulate, membranous with ten greenish nerves, the triangular base of its lobes abruptly narrowed into long slender plumose setae which are twice as long as the tube; corolla lemon-yellow; the standard very short, reniform-triangular, acute, broader than long, shorter than the slender claw; the wings oval, short clawed; keel petals oval or even broader, surpassing the wings, the blade about 6^{mm} long and the claw about 2^{mm}; ovary silky, included in the calyx tube, half as long as the slender plumose style which is much exceeded by the calyx lobes.

The somewhat varying descriptions of *Parosela Jamesii* indicate that more than one species has been distributed under this name. That the species now proposed is the *Dalea Jamesii* of Porter, *Fl. Colorado*, seems probable, but from the original as described in T. & G. *Fl. N. Am.* 308, the following points seem to separate it. *P. Porteri* is more prostrate spreading, the leaves are narrower and are shorter than the petioles, the pubescence is coarser, it has purple bracts, the flowers are yellow not purple, and the wings and keel are oval not oblong as in *P. Jamesii*.[1]

Collected at Berwind, Colorado, 1900, by *Jennie M. Archibald*, no. 244.

Petalostemon pubescens, n. sp.— Roots woody; the crown thick, simple or branched: stems numerous, the exterior ones

[1] Dr. Gray in redrawing the description for Pl. Wright. 49, seems to have so modified the original description as possibly to include *P. Porteri*.

prostrate-assurgent, the central suberect, 1–2^{dm} long, whitish with a sublanate pubescence: leaves neither glandular nor dotted, 5-foliate, nearly glabrous above, the pubescence underneath and on the petioles resembling that on the stems; leaflets spatulate-linear, sessile, 10–14^{mm} long; petioles about as long, often with a pair of diminutive trifoliate leaves in the axils; stipules filiform: spike oblong, dense, 2–5^{cm} long, 1^{cm} or less in diameter; peduncles short (1–5^{cm}): bracts scarcely equaling the calyx, obovate, abruptly acuminate, the dark purple tip obscured by the copious silvery lanate pubescence of the spike as a whole: calyx 4–5^{mm} long, the teeth shorter than the tube: petals light purple; the limb of the standard broadly cordate, about 3^{mm} in diameter, exceeded by the filiform claw: ovary and base of style softly pubescent.

Most nearly allied to *P. tenuifolius* Gray, from which it is at once to be distinguished by its very different habit, shorter broader leaflets, shorter peduncles and slenderer spikes, obovate short-acuminate purple tipped bracts, light purple petals, and the almost entire absence of glands or dots anywhere on the plant.

The species is founded on no. 247 from Berwind, Colorado, by *Jennie M. Archibald.*

Gentiana Moseleyi, n. sp.—Perennial from slender fleshy rootstocks, about 1^{dm} high, glabrous throughout, 1–2-flowered (possibly more): leaves about 4 pairs, two of which are basal and nearly verticillate, from narrowly oblanceolate and petioled below to broadly linear and sessile above, 2–3^{cm} long: the terminal flower subtended by a pair of foliar linear-lanceolate bracts often nearly as long as the calyx; additional flowers (if any) axillary in the uppermost leaves and smaller: calyx green with purple streaks, about 15^{mm} long; the lobes triangular-lanceolate, equaling or exceeding the tube: corolla dark blue, about 25^{mm} long; the lobes oblong, obtuse, exceeding the tube (15^{mm} long), 5–7^{mm} broad, conspicuously long setaceous-lacerate on the sides and often nearly to the summit which is obscurely dentate; the tube arachnoid woolly within especially toward the base: filaments stout, flattened, equaling the tube: stipe half as long as the elliptic-oblong capsule: style almost wanting.

The habit and general appearance of this excellent species is much like *G. elegans unicaulis* Aven Nelson. In fact at first glance I thought of it as that, but no one really stopping to look at it can possibly mistake one for the other. *G. Moseleyi* is certainly a perennial; the conspicuous fringe upon the corolla lobes which exceed the tube and the sessile stigmas at once mark it as distinct from the other.

The specimens were collected by *F. V. Moseley* in Boulder county, Colorado, 1896. The exact locality is not known, but it probably was in some of the higher mountains.

Polemonium Archibaldae, n. sp.—Stems tall ($4–7^{dm}$), erect, slender, sparsely pubescent but not glandular except in the inflorescence: leaves glabrate, deeply pinnately divided, the midrib merely narrowly margined between the segments and on the very short petiole, $8–12^{cm}$ long; the segments subpaired, 13–19, oblong-lanceolate: inflorescence corymbose-cymose, minutely glandular-pubescent especially on the calyx; the small cymes (5–9-flowered) erect, congested (the pedicels very short); peduncles slender, the lower $5–10^{cm}$ long: calyx campanulate, $6–7^{mm}$ long, the lanceolate lobes as long as the tube: corolla rotate-campanulate, $10–14^{mm}$ in diameter, the lobes suborbicular, as long as the tube, from deep purple to much lighter: filaments filiform, a little shorter than the corolla, glabrous except at the insertion where they are densely and finely pubescent; anthers oblong, large, 3^{mm} long: stigmas scarcely exserted.

This species is closely related to *P. filicinum* Greene, but differs from that in the somewhat narrower leaves, in the ampler inflorescence, in orbicular (not acute) corolla lobes, in the relatively shorter calyx lobes, in its erect (not declined) stamens, and in its shorter style. The inflorescence is probably also much less glandular, for Dr. Greene characterizes *P. filicinum* as being densely glandular-viscid in the inflorescence.

The species is dedicated to Jennie M. Archibald, who secured at Berwind, Colorada, in 1900, a most interesting collection. The type is in the Rocky Mountain Herbarium, no. 220 of the collection mentioned.

Monarda Nuttallii, n. n.—*Monarda aristata* Nutt., Trans. Am. Phil. Soc. n. ser. **5**: 186. 1837; not *Monarda aristata* Hook., Bot. Mag. t. 3526. 1836. This has been for some time included in *Monarda citriodora* Cerv., but any suite of specimens of the two shows that they are distinct. *M. citriodora* is a larger, coarser

plant, with broader leaves; the bracts more deeply colored, longer, more abruptly aristate and less strongly ciliate than in *M. Nuttallii*. The latter has the mid-nerve of the bracts relatively much more conspicuous than the others, and the aristate calyx lobes strikingly ciliate-bearded.

M. Nuttallii is well represented by the following specimens, all from Colorado: 166, *Professor Francis Ramaley*, Boulder, 1900; *C. S. Crandall*, Fort Collins, 1893; *Marie Holzinger*, Boulder, 1892; 614, *Baker*, *Earle*, and *Tracy*, Durango, 1898; 428 of the Hall and Harbour plants.

In this connection I would inquire why *Monarda aristata* Hook. should not be restored as a substitute for *M. clinopodioides* Gray?

Monarda Ramaleyi, n. n. — Rootstocks horizontal, rather slender, abundantly and conspicuously rootbearing: stems erect, or sometimes decumbent and somewhat flexuous, mostly simple and monocephalous, 3–6^{dm} high, glabrate below, softly lanately white-pubescent upward, densely so at the nodes, more or less purplish: leaves lanceolate or ovate lanceolate, broadly rounded or subtruncate at base, sharply but rather remotely serrate, softly pubescent especially below; petioles very short, less than 1^{cm}, the uppermost almost wanting, lanately pubescent as are also the midribs of the leaves: involucral leaves about 6 or, counting the approximated uppermost stem pair, 8, ovate, acute, entire, 2–3^{cm} long, obscurely tinged with purple: floral bracts slenderly linear-subulate, ciliate-hispid on the margins, about 1^{cm} long: calyx tubular, minutely puberulent, 8–10^{mm} long, the five equal subulate teeth very short and somewhat hispid-pubescent at base: corolla lilac-purple, softly pubescent, strongly bilabiate; the tube within the calyx very narrowly linear, dilating gradually above, the exserted portion exceeding the calyx; upper lip linear-lanceolate, but slightly curved, 10–12^{mm} long; lower lip oblong-elliptic, as long at the upper, obtuse and broadly emarginate at apex, with a short, broadly linear, cucullate, pubescent appendage from the notch; the appendage bidentate: stamens 2, exserted, exceeded by the pistil.

This species at once presents a very different appearance from the only two species with which it can be compared, viz., *M. menthaefolia* Graham and *M. stricta* Wooton. On suggesting to Professor Ramaley that it was probably

new, he very kindly supplied me with a good series of specimens from which the characters are drawn. It may at once be distinguished by its rather low, strict, usually monocephalous stems, its unusual pubescence, its almost lavender corollas, and the peculiar appendage-like appearance of the middle lobe of the lower lip.

I am informed that it occurs rather sparingly in sandy soil near Boulder creek, Boulder, Colorado, where it was collected by *Professor Ramaley* (to whom it is dedicated) June 27, 1900, no. 92.

PHACELIA HETEROPHYLLA Pursh. The Rocky mountain specimens of this species seem somewhat aberrant, but the characters so far as made out do not seem to warrant separation.

MIMULUS LANGSDORFII TILINGI (Regel) Greene? A peculiarly pubescent form was sparingly represented. It seems probable that fuller material may show this to be distinct.

LITHOSPERMUM LINEARIFOLIUM Goldie was represented by several numbers and showed much diversity. However, since these numbers represented different localities and plants in different stages of maturity no dependence can be placed on the diversity shown. In this species and its allies successive collections should be made during the season from what is undoubtedly the same community of plants.

CHRYSOPSIS FULCRATA Greene. What seems to be a pretty good match for the type number of this species, originally described from New Mexican material, was collected near Boulder.

Oonopsis monocephala, n. sp.—Caudex woody, its branches slender: stems one or more from each branch of the caudex, erect or ascending, 1–2^{dm} high, simple, uniformly leafy from base to summit, monocephalous: leaves glabrous as are also the stems, linear-oblong, sessile, acute, quite uniform in size and shape, 5–8^{cm} long, about 1^{cm} broad, the uppermost involucrating the large head: involucre hemispherical, about 15^{mm} high; the bracts oblong, rather abruptly short acuminate-cuspidate, glabrous but for some ciliate pubescence on the margins: heads rayless; disk flowers very numerous: pappus nearly as long as the corolla tube, the bristles widely spreading at maturity: akene oblong, about 3^{mm} long, sparsely and obscurely glandular.

I am aware in pronouncing this plant an Oonopsis that I am putting into this genus a monocephalous species and another rayless one, but the habit is thoroughly characteristic. The hue of the leaves, which retain their foliar character up to the heads which they surpass, the appearance of the involucre, and the floral characters are in perfect accord with the genus.

The specimens upon which the species is founded were submitted to me by Professor Ramaley, of the University of Colorado, and are the collection of *Jennie M. Archibald*, at Berwind, Colorado, in 1900, no. 257.

WESTERN EUPATORIEAE.

Eupatorium atromontanum, n. sp.—Tall, 1–2^{m} high: stems with an obscure short white puberulence, striate, greenish or mottled with purplish-brown: leaves verticillate in fours, short petioled, ample, from ovate-acute to lanceolate-acuminate on the same plant, 12–25^{cm} long, 4–10^{cm} broad, much exceeding the internodes, coarsely serrate, the teeth broadly triangular and apiculate, rather thin, prominently veined below, glabrate above and dark green, lighter and with a short fuscous puberulence underneath, sprinkled with minute, shining, resinous dots: inflorescence corymbose-cymose or more paniculate, equaled or more often overtopped by the uppermost leaves; the peduncles of the cymes arising from the axils of the leaves of the 2 or 3 uppermost verticils cinerous-pubescent as are also the numerous short slender pedicels: involucral bracts in 4 or 5 series; the outer short, elliptic; the second and third more broadly elliptic or oval, about 7^{mm} long, pubescent, with 3 greenish striae and scarious margins; the inner and longest becoming oblong and almost wholly scarious: heads about 15-flowered: corollas tubular (hardly at all dilated upwards): akene obscurely angled, dotted with resin particles, linear, but slightly shorter than the somewhat unequal pappus.

This finds its nearest ally in the somewhat polymorphous *E. maculatum* L. The more typical form of that differs from this in the thicker, usually rugose leaves which at the summit become smaller or bract-like, leaving the inflorescence naked (surpassing the leaves). That also has a harsher, more copious pubescence, different involucral bracts, and fewer flowers in the head.

E. atromontanum is represented in the Rocky Mountain Herbarium by two collections, as follows; 2251, Sheridan, July 10, 1896; 2553, Beaver creek, Black hills, Wyoming, July 30, 1896 (type).

Coleosanthus congestus, n. sp.— Roots fascicled, large, semi-fleshy, with a woody crown: stems several to numerous, ascending or nearly erect, simple, 3–6^{dm} long, minutely pubescent, obscurely striate: leaves opposite below, only the uppermost alternate, green and nearly glabrous, or obscurely roughened-scabrous, especially on the veins below, lightly sprinkled with resin particles, deltoid-triangular, with truncate or cordate base, from sub-acute to acuminate, 3–6^{cm} long, crenately-serrate, the apex entire; petioles variable, very short to equaling or surpassing the blade: inflorescence congested at the summit of the simple stems, the crowded cymes of the few heads subtended by foliar bracts, sometimes one or more additional cymes terminal on widely divaricate or ascending peduncles from the axils of the uppermost leaves: heads 10–12^{mm} high, subtended by a few loose long-acuminate bracts; the involucral bracts in about 5 series, the outermost ovate, acuminate, pubescent and ciliate on the margins; the succeeding rows passing from broadly lanceolate to broadly linear, green between the 3 or 4 raised white striae and ciliate on the scarious margin: flowers about 50: corolla narrow, tubular, about 7^{mm} long: anthers wholly included within the tube proper: style branches spatulate-clavate, the exserted portion about 3^{mm} long: akenes linear-cylindric, subglabrous, 10-striate, 3–4^{mm} long.

This is undoubtedly, in part, the *Brickellia grandiflora* of Gray, *Syn. Fl.* 105, but is certainly distinct from *Eupatorium(?) grandiflorum* Hook. *Fl.* 2: 26, and probably from *Brickellia grandiflora* Nutt. *Trans. Am. Phil. Soc.* n. ser. 7: 287. The original seems to have been a tall, probably single-stemmed plant, paniculately branched at the summit, with larger, fewer-flowered heads, and white corollas. This Oregon plant is probably in large part the *Coleosanthus grandiflorus* of the recent *Flora of N. W. America* 203, by Howell, who writes from near the type locality. The tufted habit, simple stems, congested inflorescence, and more numerous flowers of *C. congestus* seem to me to be specific characters.

The collections at hand are: 423, Fairbanks, July 10, 1894; 1687, Cummins, July 16, 1895; 4212, Battle lake, August 17, 1897; 7506, Antelope basin, July 8, 1900 (type); also Palmer lake, Colorado, August 12, 1896, by *Professor C. S. Crandall.*

Kuhnia Fitzpatricki, n. sp.—Stems 1–several, with a woody root, erect, 1^{m} (more or less) high: stems simple, rather slender, light green, obscurely striate, scarcely puberulent: leaves numerous, very uniformly distributed except near the base where they are early deciduous, green and appearing glabrous but puberulent or minutely scabrous especially on the margins or veins, thin, not impressed punctate and the resin particles microscopic, very uniform in shape and size, narrowly lanceolate, the cuneate base subpetiolate and with 1 or more linear bracts in the axils, 8–12^{cm} long, 8–15^{mm} wide, coarsely and somewhat uniformly toothed, upwardly becoming narrower, entire and in the short inflorescence somewhat reduced: cymes few and of few heads, crowded: pedicels and involucre softly pubescent; the outer bracts filiform; the inner broadly linear, acuminate: corolla purple(?), tube short, very slender, dilated at base, expanding into a much longer cylindrical throat: akene fusiform, 5^{m} long, equaled by the very fine white pappus.

This remarkably distinct species from the prairies of Iowa, I have from *T. J.* and *M. F. L. Fitzpatrick*, who collected it in Decatur county, September 25, 1899, where it is said to be common. It was distributed as *K. eupatorioides* L. (var. ?).

Kuhnia Gooddingi, n. sp.— Perennial, from a densely caespitose-tufted caudex: stems very numerous, loosely spreading, 5–8^{dm} high, simple and almost leafless below, striate and minutely puberulent: leaves numerous, crowded on the middle portion of the stem, sparsely and minutely puberulent especially on the margins and veins, linear to narrowly lanceolate, 2–4^{cm} long, entire or nearly so, more or less revolute-margined, minutely impressed-punctate on both surfaces, those of the inflorescence gradually reduced and linear-bracteate: inflorescence loosely and widely paniculate, occupying the upper third of the plant: the pedicels and involucre finely pubescent: involucres turbinate, the bracts in about five series; the outer short, lanceolate; the inner broadly linear, with villous-pubescent setaceous tip, about 4-striate, sparsely sprinkled with shining resinous particles as are also the corolla teeth: disk 10–12^{mm} high, 15–25-flowered;

corolla ochroleucous or shading to brown, slender, tubular; akene linear, finely about 20-striate, only a little shorter than the white finely plumose pappus.

No western species of Kuhnia have heretofore been described. They occur but rarely, but at least two good species seem to belong to the eastern Rocky mountains. This species now proposed is one of the strongest of these, and differs so radically in habit, to say nothing of the other characters, that it seems unnecessary to call attention to the points of divergence from the well known species.

It was secured by *Mr. Leslie Goodding*, to whom it is dedicated, in a mountain valley, West Dry creek, Larimer county, Colorado, where it occurred in the greatest abundance, usually in stony places, but with the tufted stems and woody caudex imbedded in low mounds of loose drifting soil. The type number is 8202.

Kuhnia Hitchcocki, n. sp.— Tufted-suffrutescent, the lignescent stems decumbent-spreading, each divaricately branched from the base up, dark in hue but minutely puberulent as are also the leaves: stem leaves mostly wanting (or if but little branched, very numerous), nearly linear, with a few sharp teeth, 3–4^{cm} long; those of the rigid branches numerous, small, linear, 2–3^{cm} long, passing into the bractlets: involucre usually subtended by a few linear bractlets, its bracts in about 5 series, the short outer ones broadly lanceolate, the inner broadly linear with thin scarious margins and cuspidate apex: disk corollas 20–30, the tube nearly uniform: akenes small, about 10-striate, shorter than the dull-white to tawny distinctly plumose pappus.

This species seems to belong to the arid plains east of the Rocky mountains. It has been frequently collected by Professor A. S. Hitchcock (to whom I am pleased to dedicate the species) in several of the counties of Kansas. Among the large series of specimens that his courtesy has enabled me to examine, the following may be named as typical: 211*a*, Meade county, September 1897; Edwards county, September 1897; Stafford county, September 1897; Clark county, August 1896; Kiowa county, August 1896; Barton county, August 1895.

Kuhnia reticulata, n. sp.—Caudex woody: stems several or many, ascending, 3–4^{dm} high, simple, light green, finely puberulent: leaves light green, appearing glabrous but puberulent on

the upper face and on the veins and margins, closely impressed-punctate on both faces, the veins on the lower surface raised-reticulate, oblong-lanceolate, 2–4^{cm} long, subacute, from entire to irregularly few toothed, usually some small fascicled linear leaves in the axils, smaller upward and passing into the bracts of the short inflorescence: cymes of few heads, congested-corymbose or becoming paniculate: involucre turbinate-campanulate; the bracts in 4 or 5 series, softly pubescent, strongly nervose, resin-sprinkled, shorter than the 12–15^{mm} high disk; the outer short, lanceolate; the inner broadly linear, acute: flowers about 25: the corollas linear-cylindric, but slightly dilated at base, about 8^{mm} long: style tips compressed, linear, not dilated-clavate at summit: akenes 20-striate, some of the striae more prominent than the others, linear, about 5^{mm} long, exceeded by the white softly plumose pappus.

This species is perhaps most nearly allied to *K. glutinosa* Ell., but the points of distinction are so patent that to call attention to them seems unnecessary.

The only collection of it is no. 2771, Platte cañon, Laramie county, Wyoming, August 27, 1896. Some specimens of it were distributed as *K. eupatorioides corymbosa* T. & G.

Lacinaria alata, n. sp.—Tall, 8^{dm} to probably twice as high: stem stout, striate, puberulent: leaves numerous and crowded (especially on the middle portion of the stem), quite similar throughout (root leaves not seen), glabrous, closely and uniformly punctate, linear-oblong, acute; the lower 8–12^{cm} long, mostly less than 1^{cm} broad, deflexed on the short margined petioles, upwardly becoming smaller sessile and erect, passing into the large foliar bracts of the spike: spike 3–5^{dm} long, crowded: heads sessile or nearly so, numerous (30–50), about 15^{mm} high, equally broad, 35–45-flowered: the involucral bracts in about 6 series, minutely punctate, purplish; the outer very short, ovate, acute, green, rarely slightly scarious-winged near the summit; the succeeding 2 or 3 series similar as to the foliaceous center but conspicuously and broadly scarious-winged toward summit, becoming broadly obcordate in outline, the wings from entire to dentate or even lacerate, about 1^{cm} long

and broad; the inner series longer and narrower, scarious margined all around: corolla resin-dotted throughout, 8–10^{mm} long, the broadly linear lobes half as long as the tube which is stiffly pubescent within near the base: style branches as long as the corolla; akene narrowly obovate, dark brown with short whitish spreading pubescence, about 5^{mm} long: receptacle nearly plane, with shallow alveolations.

The plants upon which this species is founded were collected by *J. H. Kimmons*, August 1895, in the Creek Nation, I. T., and distributed by Professor J. W. Blankinship as *Liatris scariosa* Willd. From this there are many characters to separate it, but attention need only be called to the reflexed lower leaves, the long foliar-bracted spike, and the alate bracts of involucre.

Lacinaria ligulistylis, n. sp.—Perennial, from an enlarged woody tuberous root: stems single, light green, glabrate below, lightly white pubescent above, striate, 4–5^{dm} high, uniformly leafy from the base up: leaves bright green, rather obscurely punctate, glabrous, usually minutely ciliate on the slightly thickened margin; the lower lance-oblong, 8–12^{cm} long, tapering into a usually much shorter margined petiole; upwardly becoming more lanceolate, the winged base shorter, gradually smaller, passing into the lance-linear bracts of the inflorescence: heads from few to several, racemose: peduncles 1–3^{cm} long, tinged with purple as are also the peduncle and rachis: involucre broadly campanulate, often 20–25^{mm} broad; bracts in about 6 series, foliar-green with dark purple scarious dentate margins; the outer short, from nearly orbicular to oval; the middle rows broadly obovate; the inner elliptic or oblong and 15–18^{mm} long: flowers 50–70, purple: corolla tube slightly dilated upward; the teeth lanceolate, one third as long as the tube, with a delicate marginal vein: exserted style branches flattened, as long as the corolla, light purple, conspicuous and superficially suggesting the slender rays of some Erigeron; akene flattened, finely pubescent, nearly as long as the corolla tube.

The Rocky mountain forms of Lacinaria that have passed as *L. scariosa* (L.) Hill are clearly distinct from the eastern forms. That, even with the Rocky mountain form eliminated, *L. scariosa*, as applied to the eastern forms,

is still an aggregate seems to me more than probable. In spite of the extended synonomy of this species, the various names all seem to be associated with the forms of the eastern or the Mississippi valley states. Some of the descriptions of *L. scariosa*, however, probably cover or may even be founded upon the western or Rocky mountain form, notably that of Hooker, *Fl.* 1 : 306.

The species now proposed is at once distinct from the *Serratula scariosa* L. and the *Liatris scariosa* Willd., and surely from the spicate forms of the Mississippi valley. The smooth leaves gradually diminishing upwards, the relatively short margined petioles also diminishing upward, the clearly racemiform purple inflorescence, the large heads, the appressed involucre, the very conspicuous style-branches, and the numerous flowers will serve to distinguish *L. ligulistylis*.

The following collections are cited as typical: 1651, Laramie peak, August 8, 1895 (type); 691, by *C. F. Baker*, Pagosa springs, Colorado, August 30, 1899; 4554, by *F. H. Snow*, Colorado; *G. E. Osterhout*, Steamboat springs, Colorado, August 24, 1899; less typical my numbers from Inyan Cara divide, August 20, 1892; and Buffalo, July 26, 1896.

STUDIES IN ARNICAS.

The collector and the student of the Rocky mountain Arnicas has in the past found many difficulties with which to contend. So many of the species attributed to this region were originally described from such widely different geographical ranges that it ought to have been expected that no close agreement would be found between our species and those of the earlier investigated localities. The recent activity in taxonomic botany is bringing to light many real novelties and separating many of the heretofore uncertain but well-known forms. It is perhaps inevitable that at such a time some confusion should result, but perhaps the sooner synonyms and homonyms are cleared up the better. The following have come under my observation:

Arnica multiflora Greene, Pitt. 4 : 162, evidently is *A. Columbiana* Aven Nelson, Bot. Gaz. 30 : 200, since both are, in part, founded on the same collections and the same numbers are cited. The latter name is the earlier by two or three months. Dr. Greene's *A. Columbiana* (Pitt. 4 : 159) having thus become a homonym it may become **Arnica Greenei**, n. n.

Arnica platyphylla, n. sp.—Perennial from woody rhizomes, 3–6 dm high, rather slender, the internodes subequal, nearly glabrous throughout, the leaves very thin and delicate in texture: the leaves that spring in fascicles of 3–5 from the rhizome oval to oval-subcordate, sinuately dentate as are also the stem leaves, obtuse or acute, ciliolate on the margins, 4–6 cm long, equaled by the slender petioles: stem leaves 2–4 pairs and a pair of sheathing scales at base, all closely sessile by broadly rounded or truncate base; if only 2 pairs, similar in size and shape; if 4 pairs, the upper and the lower smaller than the two middle pairs; from nearly orbicular to broadly ovate and subacute, 5–10 cm long: heads 3–5; if three, on slender nearly equal peduncles, subtended by ovate-acuminate bracts 2–3 cm long; if five, the lowest pair from the uppermost leaves and borne on elongated slender petioles: involucres somewhat turbinate, slightly glandular-pubescent as are also the peduncles; scales thin, narrowly obovate-acuminate, in one series: rays few, long, bright yellow: tube of disk corollas pubescent, very slender, abruptly dilated into a wide cylindrical glabrous throat with slender erect teeth: akenes narrowly linear, 5 mm long, equaling the fine white hardly scabrous pappus.

This is seemingly a well marked species, occurring in the moist woods of the northern Rocky mountains. I have seen four collections of it as follows: *Henderson*, Cascade mountains, Oregon, July 18, 1896, distributed as *A. latifolia; Sandberg* and *Leiberg*, Stevens pass, Washington, distributed as *A. Chamissonis*, August 1893; *R. S. Williams* (no. 443), Columbia falls, June 18, 1894; Belt mountains, Montana, July 24, 1899. Of the latter two I cannot be very certain, as they are not now at hand. This species seems nearest to the recently described *A. ventorum* Greene (based upon one of my numbers), a species of which I now have several collections.

Arnica stricta, n. sp.—Very erect with gradually tapering stem, 2–3 dm high, tomentose pubescent throughout: leaves about 5 pairs, the lower pairs exceeding the internodes, gradually smaller upward, the upper half of the stem nearly naked; the lowest pair lanceolate, acute, 3–5 cm long, tapering into a slender petiole usually shorter than the blade; the next 1 or 2 pairs similar but with shorter petioles; the upper and smaller pairs sessile by

a broad base: inflorescence of about 5 heads subtended by a pair of ovate-lanceolate bracts, 1–2 cm long, in a close rounded corymb, the terminal head and the first pair very short peduncled: terminal head much the largest, 10–12 mm high and about as broad: involucral bracts in 2 series, shorter than the disk, narrowly oblong, obtusish, the tip tinged with purple and tomentose-ciliate: rays few, short, broad, slightly narrowed at apex: tube of disk corollas pubescent, the glabrous throat scarcely dilated: akenes very minutely pubescent; pappus dirty-white, minutely scabrous.

The specimens on which this species is based were collected in 1892 by Mr. J. D. Parker, somewhere in southern Wyoming. Specimens were sent to the Gray Herbarium for determination. The name returned was *A. foliosa* near var. *incana* Gray. Now that Dr. Greene has helped us to a more definite knowledge of *A. incana* (Pitt. 4: 169), this may with safety be designated by a name.

Arnica celsa, n. sp.—Perennial from horizontal rootstocks and fleshy roots, erect, tall, 4–6 dm: the strict stems lightly striate, sparsely pubescent with flat spreading hairs, upwardly becoming also obscurely glandular-viscid: leaves (exclusive of the foliar bracts) 6–8 pairs, puberulent and sprinkled with microscopic shining resin particles, narrowly oblong or oblanceolate, tapering to both ends, many of them 3-nerved; the lower small, 2–3 cm long, equaled by the slender petioles which abruptly dilate into the equally long ocreae; ocreae and leaves gradually shorter upward; middle stem leaves longest (8–10 cm), sessile or with short petioles and ocreae; the uppermost sessile and partly clasping: lower internodes short, much exceeded by the leaves, gradually longer upwards and above much exceeding the leaves: heads 3–5, on rather slender leafy-bracted peduncles; involucre and peduncles moderately glandular-viscid; the bracts approximately uniserial, oblong, much shorter than the 12–15 mm high disk: rays 12–20, about 7-nerved, 2 or 3-toothed, 10–14 mm long: tube of disk corollas slender and pubescent below, gradually dilated into an equally long glabrous sub-cylindric upper portion with short spreading glabrous teeth: akenes sub-glabrous,

nearly linear, tapering downward, the scabrous pappus equaling the corolla tube.

This excellent species was found growing in abundance on the wet, meadow-like banks of a mountain streamlet at an altitude of 8000 feet. The nearest ally known to me is *A. ocreata* Aven Nelson, from which it differs in its pubescence and wholly different disposition of its leaves. The habit of the inflorescence, too, is very unlike, which in the species now proposed consists of subequal heads always corymbosely disposed.

No. 7643, Tie city, Albany county, July 20, 1900, is the type.

Arnica rhizomata, n. sp.—Conspicuously rhizomatous, the creeping rootstocks slender, sheathing-bracteate at the nodes, giving rise at intervals to the erect leafy stems and a few fleshy roots: pubescence whitish, soft, almost arachnoid, minutely granular-glutinous underneath the pubescence on the inflorescence: stems 2–5 ^{dm} high: leaves 5–7 pairs, rather uniformly distributed, oblong-lanceolate, from obtuse to acute; the lowest pair with short scarious-margined petioles, early deciduous; the next 1 or 2 pairs 6–9 ^{cm} long, about 2 ^{cm} broad, on short margined petioles which dilate at base to form the short ocreae; the upper pairs sessile, shorter: heads 3–5, 10–12 ^{mm} high, or sometimes more numerous and then smaller: peduncles mostly short, erect, the lateral often exceeding the terminal: involucre campanulate, the bracts much shorter than the disk, narrowly oblong, obtusish: corolla long-pubescent on the tube, sometimes a few straggling hairs on the lobes: akenes linear, almost glabrous, the pubescence short and scattering, half as long as the 8 ^{mm} corolla: pappus fulvous or dirty-white.

This species has been collected several times and has been held as a form of *A. foliosa*, or rather as variety *incana*. Such a disposition is no longer tenable, neither am I able to refer it to the species (*A. foliosa* Nutt.). It seems rather to belong to a section of which *A. ocreata*, *A. celsa*, and this are the principal members. In so far as this region is concerned, the following collections represent it: 8012, Lincoln gulch, Albany county, August 8, 1900 (type); 1417, *B. C. Buffum*, Pine creek, 1892; Green mountain, July 6, 1896; 3587, North Vermillion creek, July 17, 1897.

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STUDIES ON THE GEOTROPISM OF STEMS. II.[1]

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(WITH THREE FIGURES)

THE review of my earlier papers on this subject, written by Czapek for the *Botanische Zeitung*,[2] is in error on a point of priority and on the interpretation of the results. Sachs never showed that if a stem be split and the halves placed horizontal the under one would grow faster. In Sachs' experiment referred to in the review the average elongation of the two faces of the upper half stem was 9.7 mm, that of the lower half only 9.0 mm. If the experiment had been continued longer (see footnote BOT. GAZ. **29**: 189. 1900) the relation would have been reversed. The review concludes:

> Insbesondere kann der Ref. sich der Ansicht des Verf. dass diese Erscheinung alle Theorien, welche den Sitz der geotropischen Reactionen in beiden Längshälften annehmen, ausser Kraft setze, nicht anschliessen.

I do not hold and have never expressed such a view. The phenomenon in question proves that both halves *do* share in the reaction, which therefore does not take "place entirely in *either* half." As Czapek construed my conclusion, it is no wonder that he disagreed.

3. Positive geotropism in the hypocotyl or cotyledon.

The descending axis of a plant must grow and become fast in the ground before the negative geotropism of the ascending axis can result in the erection of the growing tip. That the former does break first from the seed is a matter of universal observation. In the popular conception this first outgrowth is simply the "root;" but that this idea is not exact is recognized, for

[1] The first number appeared in BOT. GAZ. **29**: 185–196. 1900.

[2] Bot. Zeit. **58**: 200. 1900.

instance, by the disposition in many texts to substitute the word caulicle for radicle for the part of the embryo below the insertion of the cotyledons. In all Dicotyledons a part of the stem is distinguishable below the cotyledons, and in a majority it elongates to carry the cotyledons into the air. The elongation of the caulicle is the first visible growth. When the caulicle is largely a stem structure, and only the tip represents the future root, the beginning of growth is in the stem. In all cases the caulicle promptly bends downward. We have here apparently, then, positive geotropism of the hypocotyl, which so far as I know has not hitherto been recognized or investigated.

Lupinus albus, in the size and uniformity of the seedlings and their rapid growth, is the best material I have found for this work. Both in the seed and on the seedling there is usually a well-defined line where the root merges into the stem. In the first cultures I marked this line with India ink on the swollen embryos, to be certain that it was the same one separating root and shoot in the seedling, and found that such was constantly the case. In order to have the entire descending axis free to curve, I usually removed the seedcoats, after swelling, but before any considerable growth. This was not necessary for the mere demonstration that a part of the hypocotyl bends downward, but when germination took place within the coats a part of the hypocotyl was often constrained by them. Their removal was probably without effect on germination or growth, though in an experiment to ascertain its influence the peeled plants grew slightly faster.

One culture of plants is reported upon here in detail, to show the constancy of the results, and the range of variation that may be expected. The seeds were put into water October 1. On October 2, 9:00 A.M., the coats were removed. Fifteen very uniform embryos were selected and pinned with the axis horizontal. The length of the hypocotyl was 6^{mm}, of the root 1.8^{mm}. The table shows the result after 24 hours. The last column, showing how far above the base of the hypocotyl the curve of least radius occurred, is the significant one.

	Hypocotyl length	Root length	Curve above base of hypocotyl
1	8.mm	6.mm	5.mm
2	10.	8.	7.
3	8.	9.	4.
4	8.	9.	4.
5	8.	10.	5.
6	8.	5.	4.
7	8.	5.	5.
8	10.	10.	7.
9	9.	7.	6.
10	9.	7.	6.
11	10.	9.	7.
12	9.	7.	6.
13	9.	4.	5.
14	9.	5.	6.
15	9.	7.	7.
Av.	8.8mm	7.2mm	5.6mm

In all except three plants, in which it fell at the middle, the sharpest curve was above the middle of the hypocotyl (*fig. 1*). In several of the plants the curve began immediately at the insertion of the cotyledons. Two of the plants of this series were put into water culture vessels, and when the elongation of the hypocotyl was finished, in a south window, the points where the radius of curvature had been least were 20 and 22mm above the foot of the hypocotyl. *The curve had disappeared.*[3] In three plants of another experiment the part of the hypocotyl below the sharpest curve elongated to 17.5, 18.0, and 19.0mm, the curve being eliminated.

With somewhat older seedlings the result is less uniform. With twelve plants whose hypocotyl was ca. 10mm and the root ca. 2.0mm long, placed horizontal for twenty-one hours, the result was that the sharpest curve in three hours was in the hypocotyl, in six hours at the line of separation, and in three hours in the root. Before the experiment the plants had been in imperfectly saturated air, which shortens the growing region, as compared with plants grown in water or saturated air.[4]

The first attempt at an explanation of the behavior of the hypocotyl was by a study of its anatomy. If the transition from stem to root character in the internal tissues or their arrangement occurred higher up than the external line of demarcation, there would be a fine prospect of demonstrating the relation of

[3] From clinostat experiments I know that both negative geotropism and rectipetality are concerned in this straightening.

[4] SACHS, J.: Ueber das Wachsthum der Haupt- und Nebenwurzeln. Gesammelte Abhandlungen 807. From Arb. bot. Inst. Würzburg 1. 1874.

POPOVICI, A. P. (Bot. Centralbl. 81 : 33. 1900) shows that several but not all factors checking growth shorten the growing region. For influence of insufficient water see p. 95.

the particular tissues concerned in it to the geotropic irritability. With this idea in view, I made a careful study of the histology of the root and hypocotyl. Seedlings which have just curved are not satisfactory material because of the immaturity of the tissues and the amount of plastic material present, and the observations on maturer stems which had formerly shown themselves positively geotropic make much study of very young plants superfluous. The apparent line of separation between root and hypocotyl is the real one, as to the epidermal tissues; the stomata[5] descend to it, and root hairs occur only below it. In the cortical parenchyma there is no sharp distinction between stem and root, nor between different parts of the hypocotyl, not even when, as it matures, chlorophyll becomes more abundant in the normally better lighted upper part. In the stele[6] the rotation in the arrangement of phloem and xylem is gradual, but usually begins below the transition line in the epidermis, and is completed at some distance (in one very extreme case 17^{mm}) down in the root. There is then nothing at all in the histology of the hypocotyl that can give a clue to its geotropic variability. This does not prove, however, that the explanation is to be sought in the finer structure of individual cells.

FIG. 1.—Young seedling of *Lupinus albus*, showing downward curve in the hypocotyl.

The truth is rather that the downward curve occurring in the hypocotyl is a response to a stimulus perceived by the root tip. This is not easy of absolute proof, but the evidence seems to warrant fully the conclusion. The "bent tube" method of demonstration is inapplicable because it is during the very first growth that the phenomenon in question occurs. Decapitation

[5] Near the base of the hypocotyl most of the stomata are considerably elevated above the general surface.

[6] I use the word as a matter of convenience for the bundles and pith. It is not sharply delimited from the cortex.

experiments are at best unsatisfactory, or they would have definitely determined the functions of the root tip without controversy decades ago. Mine were as consistent as they are likely to be, or as can be expected from a method which does great violence to the health of the plant, and in which any unsteadiness in the operation may entirely alter the result. When no traumatic bending occurred, the growth of horizontal decapitated plants was straight for more than twenty-four hours, and nearly always for more than forty-eight. In the end there was usually a downward curving in the basal part of the hypocotyl, but never farther up, where the curve, if any, was in the other direction. The downward curve usually occurred before a new growing point became evident, as is the case too when the response is by the root.[7] In every respect the part of the hypocotyl which would execute a positively geotropic curvature is influenced by removal of the root tip, just as the responsive zone of the root would be in older plants. The interval during which a wound suspends the geotropic perceptivity in older hypocotyls is a very few hours at most, instead of about two days.

Better evidence than decapitation can yield is obtained from a careful study of the distribution of growth in length along the young root and hypocotyl, and its relation to the location of the curve. For a basis of comparison this relation is first shown with older plants, in which the root alone curves. The plants had been germinated two days, and were marked off in 1^{mm} zones and placed horizontal at 10:30 A. M., November 19. The result at 4:00 P. M. the same day is tabulated. The first column is the length of the roots at the beginning of the experiment.

After twenty-nine and a half hours the average growth had been 20^{mm} and the curve was 90°, at about the same place. After five and a half hours, at the first measurement, the most growth had been in zones 3 and 4, but I could not measure it accurately enough to include it in the table. The experiment, like all in which the contrary is not stated, had been carried on in saturated air.

[7] Literature in CZAPEK: Ueber den Nachweis der geotropischen Sensibilität der Wurzelspitze. Jahrb. f. wiss. Bot. **35**: 314–5. 1900.

	Root length	Growth	Zone most curved	Curve	Growing zones
1	20.mm	2.0mm	3–4	75°	5
2	19.	1.5	5	70	5
3	5.	1.8	4	90	5
4	14.	1.4	4	90	5
5	24.	1.8	4	60	5
6	19.	1.0	3–4	65	5
7	15.	2.6	4	60	5
8	22.	1.6	3–4	70	5
9	14.	2.4	3–4	50	5
10	33.	3.5	3–4	50	6
Av.	18.5mm	2.0mm	4	70°	5

The subjects of the experiment whose result is next tabulated had been soaked twenty-four hours. The coats were removed and the "caulicle" was marked off into 1mm zones, and the embryos were fastened horizontal. The first column gives the total length of the descending axis; of this the rudimentary root was 1.9–2.5mm. Figures in italics are the zones of sharpest curvature. All zones of the hypocotyl grew in length, but the growth reached a minimum at some distance from the tip which I have construed as limiting the growing region of the "root." The experiment began at 10:30 A. M., November 19. At 4:00 P. M., November 20, all seedlings were curved 90°.

	Length	4 p. m. November 19		Curve	4 p. m., November 20		Growing zones
		Growth			Growth		
1	9mm	0.6mm	*3*	20°	17mm	*5*	6(+)
2	9	0.8	*5*	40	16	*5*	5
3	7	0.8	*4*	30	16	*4*	5
4	7	0.2	*3*	20	16	*5*	5
5	8	0.4	*4–5*	30	17	*4–5*	5
6	7	?	*2–3*	10	11	*4*	4
7	7	?	*3–4*	10	14	*5*	5
8	8	?	*3*	15	18	*4*	4
9	9	0.4	*4*	15	15	*4*	4
10	8	0.5	*4*	40	15	*4*	4
11	7	?	*2–4*	15	13	*4*	4
12	9	0.3	*4–5*	15	13	*4–5*	5
Av.	8mm	0.3mm	*3*	21°	15mm	*4–5*	4–5(+)

The older plants, subjects of the preceding experiment, were growing so rapidly that the first observation (after five and a half hours) was too late to show the gradual retreat from the tip of the region of curvature. But in roots it always happens,[8] as in the base of the stem in these very young plants, that the curve first appears near the tip and gradually moves farther away. Of course if the growth is rapid so will be the development of the curve.

In the base of the hypocotyl, then, the downward curve occurs only in a zone not separated from the root tip by any mature tissue, and not at most as remote from the tip as the extreme limit of what may fairly be considered the apical growing region. In these points, and in all other visible details of the execution of the response, it agrees with the familiar manifestations of positive geotropism in roots. From this and the decapitation experiments, and from the subsequent elimination of the curve by later growth, the conclusion seems obvious that the response is to a stimulus received at the root tip.

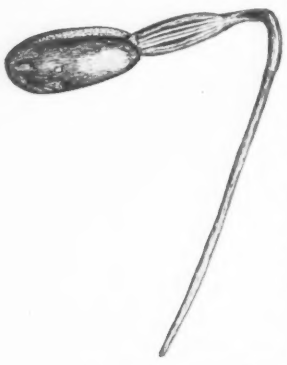

FIG. 2.—Young seedling of *Pinus Sabiniana*, showing downward curve in the hypocotyl, the curve having been increased a little to form the arch which pulls the cotyledons from the seed.

Similar but less complete observations have been made on *Robinia Pseudacacia*, *Helianthus annuus*, *Cucurbita Pepo*, *Eucalyptus globulus*, and *Pinus Sabiniana* (*fig. 2*). The embryos of Robinia, with radicles 0.5^{mm}, and hypocotyls 2.0^{mm} in length, were fastened horizontal. In one day the hypocotyl became 5.4^{mm} (average of ten plants) long, and the root 5^{mm}, the curve of least radius being 3^{mm} above the line of separation, that is, it was above the middle of the hypocotyl. Two plants were placed in water culture and the curve grew out. My observations on the anatomy have no value here, for the reason explained in the treatment of Lupinus. Decapitation was tried on Helianthus

[8] SACHS, *l. c.*, pp. 831, *seq.*

and Cucurbita, with results unsatisfactory, but, so far as they showed anything, agreeing with those on Lupinus.

Uninjured Cucurbita freed from its coats behaves at first exactly like Lupinus, but later the hypocotyl sometimes becomes concave below, even when the root tip has grown some centimeters away from it. The behavior of these older Cucurbita hypocotyls is exceedingly various, but can in no instance be closely related to the positive geotropism of very young hypocotyls. Sometimes the hypocotyl becomes concave on the side where the peg forms, apparently under the peg's influence.[9] This is not geotropism at all, though the concave side is normally beneath, because the peg grows there. Later the stem may become concave below, next to the cotyledons, in an attempt to form the arch which in nature breaks through the ground, pulling the cotyledons after.[10] This is real and fixed geotropism, not epinasty or nutation (unfixed geotropism). Frank, Vöchting, and others have described similar behavior in the peduncles or pedicels of various plants. That it is not dorsiventrality in Cucurbita is shown by its occurring independently of the plane in which the cotyledons are placed. But they subsequently become erect on the clinostat. The curve in the other direction (negatively geotropic), described for Cucurbita in the first of these studies, is also early evident. Double curves are very common, often about equaling each other and leaving the direction of the root unchanged. The whole subject is not really relevant here, and I leave it in the hope that promised papers by Pollock[11] and Noll[12] will explain my diversity of results.

The phenomenon which this paper describes shows anew that the structure of stems does not demand that the geotropic response they execute shall be negative, and that root structure

[9] DARWIN and ACTON: Physiology of plants, 193 *fig. 38A*.

[10] DARWIN and ACTON: *l. c. fig. 38B*.

[11] Prelim. paper before Soc. Plant Morph. and Physiol. Dec. 1899.

[12] Sitz. ber. Niederrhein Ges. f. Naturf. u. Heilkunde zu Bonn (S. A.) p. 3. 1900; also Jahrb. f. wiss. Bot. 34: 461. 1900.

is not essential to the positive response; but that the more characteristic feature in both organs is the perception. The clearness of the distinction between perception and response demands that we discriminate in the use of words to name the two processes. Tropism itself is the disposition to *respond* by turning or bending, and has no necessary reference to the place or manner of the perception of the stimulus, more than that the two processes be some way connected in space and time. The young hypocotyl bends downward, and is therefore prosgeotropic. For the act of perception Czapek proposes the word "aesthesis."[13] The root tip is prosgeoesthetic; it cannot possibly be geotropic because it cannot actively turn. The very young hypocotyl seems not to be directly irritable at all by gravity, but when it becomes so it always bends upward, that is, it is apogeoesthetic. With perception and execution, and transmission when the two other processes do not occur in the same place, the performance is complete. Czapek's introduction of a "Reflex-centrum"[14] as a potential link between the organ of perception and that of response, and as a seat of interpretation and decision, seems to me unnecessary,[15] and is without any empirical support. It is simpler and hence preferable to suppose that the organ of perception itself in the act of perceiving determines the direction of the response, whether or not it itself executes it. The manifestations of irritability in plants, like those of instinct in animals, are very short-cut psychic processes, and constantly dispense with steps which would be necessary to the attainment of the same end by the exercise of intelligence. On many grounds, the perception should be regarded as the characteristic and decisive though invisible feature of the entire phenomenon in plant irritability.

There is supposed to be a considerable number of instances

[13] Weitere Beiträge zur Kenntniss der geotropischen Reizbewegungen. Jahrb. f. wiss. Bot. **32**: 285. 1898.

[14] *L. c.* 294. Tropisms were called "Reflexbewegungen" by Oltmanns (Ueber die photometrischen Bewegungen der Pflanzen, Flora **75**: 265. 1892), but the elaboration of the idea is Czapek's.

[15] NOLL: Ueber Geotropismus. Jahrb. f. wiss. Bot. **34**: 492–496. 1900.

of alteration or reversal of irritability during the development of plants or their parts, independent of any changes in external conditions. At first sight the young hypocotyl of Lupinus seemed to present such a case, but investigation shows that there is no change in the nature of the perception in any esthetic tract, but merely change in the zone controlled. Very possibly, renewed study of some other cases, such as the erect tip of runners, or the tips of many climbers — at first seemingly positively heliotropic, but later appressed to the support — will show that no esthetic center undergoes any essential change; but rather that different parts of the growing region are under different control, or that the development of new members introduces automatic curvatures (nastie), or that the tendency to symmetry (autotropism, rectipetality) eliminates curves in parts which grow out of the zone of influence of an esthetic center. Nutations too suggest themselves here.

Most intimately related to the positive geotropism of the hypocotyl is that of the cotyledons of numerous monocotyledons, serving at the apex as organs of absorption in the endosperm, but elongating at the base and carrying the remainder of the embryo out of the seed. These have long been known to be positively geotropic.[16] I have made the same experiments on these as on Lupinus, and so far as the initial downward curve is concerned with strictly analogous results. Several seeds were tried, of which Phoenix and *Yucca angustifolia* were found most suitable subjects.

The growing region of Phoenix is rather long, though elongation is considerable throughout most of it. The root begins to develop after the elongation of the cotyledon is about complete. The first table of results is from six plants of very different size, on four of which the root was still only a rudiment. The

[16] SACHS: Ueber die Keimung des Samens von Allium Cepa. Gesamml. Abh. 646-647; from Bot. Zeit. February 1862.

FRANK: Lehrbuch 1: 465.

There is a paper, which I know only by a very brief notice in Bot. Jahresb. 15: 622, by M. Lewin (Bidrag till hjertbladets anatomi hos Monocotyledonerna, in Sv. V. Ak. Bih. III. 12: —. 1887), giving a list of plants with such cotyledons.

experiment began November 30, at 12 noon, the plants being marked into 1mm zones and placed horizontal. In the first plant the growth was in the root; in the second, in the cotyledon and root; and in the others in the cotyledon. In the larger plants, with more rapid growth, the execution of the curvature was prompter, and with the longer growing region the curve was farther from the tip; but it very evidently made no difference whether the curve was in the root or the cotyledon. In either case it was obviously in the apical growing region, in immedidiate connection with the sensitive tip. It is interesting to note that in the youngest plants, when the cells of the apical meristem are probably not yet dividing actively, they already exercise their function in irritability.

	Length	December 1, 9 a. m.				December 2, 9 a. m.				December 3, 9 a. m.			
		Growth	Zones grown	Zone curved	Curve	Growth	Zones grown	Zone curved	Curve	Growth	Zones grown	Zone curved	Curve
1	67.0mm (root=5.5)	2.5mm	1–5	3 most	70°	5mm	1–5	3–4	80°	7mm	2–5	3–4	90°
		1.0	5–10	....	10	....	....	....	10	1.5	5–10	....	
2	46.0mm (root=1.6)	trace	1–10	3	trace	1.6	2–7	3–4	70	3.5	....	3–4	90
3	17	1.3	1–5	3–4	50	3	2–5	3–4	90	5	....	3–4	90
4	10	.....	....	....	....	0.5	....	....	....	0.8	....	2	20
5	5	.....	....	....	....	1.0	2–3	3	10	1.5	2–3	2–3	45
6	2	.....	....	....	....	1.0	....	....	....	1.5	....	....	15

The next table contains nothing new, but is introduced to emphasize by numerous instances the fact developed in the preceding experiment that the curve in the cotyledon is in exactly the same position in the apical growing region that it would be in older plants where the growing region is all in the root. In most of these plants the rudimentary root was less than 1mm long. The experiment began January 16, 9:00 A. M., when sixteen seedlings were marked and fastened horizontal; one proved unsound. The curve is a little farther from the tip than the most elongated zone, just

as occurs in roots when the experiment lasts more than a few hours.

	January 16	January 17, 9 p. m.			
	Length	Growth	Zone most grown	Zone most curved	Curve
1	11 mm	3 mm	3	4	90°
2	12	7	3–4	3	75
3	6	4	2	3	90
4	11	7	2–3	3–4	80
5	14	7	3	3–4	90
6	14	6	3	4	90
7	19	3	3	4	95
8	7	5	2	3	70
9	2+	3	2	2+	50
10	15	5	3	4	70
11	9	7	2–3	4	90
12	9	1	1	2–3	70
13	5	3	2	2–3	90
14	4	3	2	3	85
15	10	6	3	4	85

The root of Yucca begins to grow earlier than that of Phoenix, and a considerable part of the growth of the cotyledon takes place afterward in the development of the elbow from whose inside the plumule breaks, as shown in *fig. 3*. Yucca is more like Allium than is Phoenix, but in neither does the cotyledon develop visible chlorophyll. Experiments with a considerable number of Yucca plants were perfectly harmonious during the first growth, and it will suffice to report on three typical plants. The first two seedlings were marked and placed horizontal November 9, 5 : 00 P.M.

1. Length 9 mm, of which root is 4.5 mm. November 10, 11 : 00 A.M.: growth in zones 1–3, 2.5 mm, mostly in zone 2 ; curve 85° in zone 2 ; in zone 6–9 growth 0.8 mm without curve. November 12, 11 : 00 A.M.: growth in zones 6–9 is 1.4 mm, still straight.

2. Length 5 mm, of which root is 2 mm. November 10, 11 : 00 A.M.: no appreciable change. November 11, 12 : 00 A.M.: growth in zone 1, 0.4 mm ; curve 15° ; trace of growth throughout ; growth above zone 5, 2.0 mm without curve. November 12, 11 : 00 A.M.: growth 1 mm in zones 1–3 ; curve 40° ; growth above 5, 2.8 mm, still straight.

3. Began November 22, 9 : 00 A.M. Length 3 mm, of which root is 1 mm.

FIG. 3.—Older seedling of *Yucca angustifolia*.

November 23, 3:00 P.M.: growth 6 mm, mostly in zone 1; but curve of 90° mostly in zone 3, doubtless made before most of the growth in the root.

In Yucca, as in Phoenix, the downward curve takes place in root or cotyledon, in whichever the most rapidly elongating part of the apical growing region falls. But the elongation of the more remote parts of the cotyledon is not at first accompanied by any curve at all. Afterward, in the formation of the elbow, a combination of curves develops. These are in part probably geotropic, but are in part not under the direct influence of gravity, being executed in the development of structures whose initial position gravity determines. For the same reason as in the case of Cucurbita, a further treatment of these later curves is unnecessary here.

The common statement is literally true, that these cotyledons are positively geotropic. But the meaning that has been conveyed by the words is only half correct. They do curve downward, but cannot perceive the gravity stimulus in a way that would make them curve so. As in the hypocotyl of Lupinus, any positive geotropism they may exhibit is under the control of the *punctum vegetationis* of the root, which alone is positively geoesthetic.

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BRIEFER ARTICLES.

NOTES OF TRAVEL. VI.[1]

THE BOTANICAL INSTITUTE OF NETHERLANDS INDIA.

THE gardens of Buitenzorg, Java, have been described so often that their name should by this time be familiar to every American botanist, The institution has grown so rapidly in the last few years, however, that a short description of the improvements made may be of interest to any one who expects to visit Java, and to all who are interested in the development of tropical botany. Although the Institute bears the name "botanical," it has many decided agricultural features, and on account of its various divisions and the nature of the subjects under investigation would be called by many Americans a most unusually well equipped station.

The impression made upon the writer in 1896, during an eight months stay in these gardens, was that they offered unrivaled opportunities for study, a wealth of interesting material, and surroundings full of the most interesting oriental sights. After three years' absence, much of which time has been spent in a study of other botanical gardens and institutions, I find that Buitenzorg still possesses the charm and offers even greater opportunities than in 1896. During the last three years, under Dr. Treub's excellent management, five new buildings have been erected. They consist of a double laboratory in which tobacco and coffee are investigated, a very comfortable pharmaceutical laboratory, a new library building which now holds the most complete collection of botanical works in the tropics, a luxuriously appointed office building, and a very pretty tropical bungalo for Dr. Treub. The construction of the laboratories is very substantial. They are all one story buildings with concrete floors, projecting tile roofs, and numerous large windows which in this latitude let in a flood of light and require white shades.

Tables, desks, cases, and shelves are kept scrupulously clean and neat, and in this regard are in strong contrast with most tropical institutes, in which a musty smell pervades everything. Dr. Treub has given in the first number of his *Bulletin de l'Institut Botanique de Buitenzorg*, published in December of 1898, an excellent sketch of the gardens and

[1] No. 5 of this series was lost in transit.—ED.

their personnel. He has included also a description of the publications of the Institute, an estimate of the necessary expenses of a stay at the gardens, and the cost of the sea voyage from Europe. This first number of the *Bulletin* will be sent to any botanist who writes for it with the idea of preparing for a stay at the gardens.

The new quarter, to which Mr. Wigman, the head gardener, had transferred nearly all of the climbing plants, was in 1896, like all such newly planted ground, unsatisfactory to look at. It has now grown until it is an attractive portion of the gardens, and the new avenue of canary trees in it, which was planted to rival the old avenue (for which the gardens are famous in the eyes of travelers), is already very handsome, with its regularly rounded tree tops and light gray trunks. A water-garden which had just been laid out in 1896 is now indistinguishable from older parts of the garden, and the fern quarter and collection of Pandanus, of which photographs have been so often published, have grown more interesting with their coatings of epiphytic algae. The small nursery, which was large enough three years ago to reproduce all the plants needed in the gardens, has been more than trebled in size, and packages of seeds and cases of plants are being sent all over the archipelago (2294 packages and cases in 1897), as well as in exchange with all the principal botanic gardens of the world.

Native labor is being utilized in a new printing office in the gardens, where all small forms and even scientific periodicals are printed, the compositors being Javanese who do not understand a word of what they set up. The work is done very slowly, and the proof reader's patience is taxed to the utmost, but because of the low price of labor and the inconvenience of having the work done in Batavia or Amsterdam is very great, the office is a great convenience.

I had the pleasure of accompanying Dr. Treub and Mr. Wigman in one of their early morning strolls, in the course of which they bargained with two neatly dressed Javanese land owners for some paddy fields of which to construct experimental plats. In response to Dr. Treub's and Mr. Wigman's inquiries the Javanese replied with respectful salaams and remained sitting on their heels as they would before a raja. These new plats which were purchased are to be under the supervision of a newly appointed specialist, whose acquaintance with Javanese vegetables and other native food plants will enable him to select and improve them, and to distribute information among the natives regarding the best methods of their culture.

The new laboratory for pharmaceutical research is a model of compactness and convenience. The library building, which was the generous gift of Mr. Janse, of Amsterdam, has now not only the increased library of the gardens but the considerable collections of books formerly belonging to the scientific society of Batavia. The removal of the library from the herbarium building gives Dr. Boerlage greater space for his rapidly growing collection, and the old building, formerly occupied as the pharmaceutical laboratory, is to be utilized for an exhibition of economic plant products.

A lively interest in the fruits of the island has been awakened among the planters, and a horticultural society with more than 300 members has been formed. The first exhibition of fruits, which was held in December last, was a great success, and the garden authorities hope through cooperation with members of the society to secure a collection of the best varieties of fruits, and by distributing grafts from these, to replace the inferior seedling kinds, which now furnish the fruit for the tables of the Europeans. A seedless doekoe (*Lansium domesticum*) has already been found, and other superior varieties are known to exist in the island. Almost everywhere in the tropics fruit trees are wild, and it is one of the curious observations which a traveler makes that little is done to improve fruits which are evidently capable of very great improvement. There are mangosteens which without selection are nearly or quite seedless, and yet Europeans choose to plant seeds instead of grafts, and still have a strange fear that a grafted tree will be a short-lived sickly thing and not repay for the extra trouble taken with it. The new horticultural society should do much to enlighten the planters and enable them to plant and breed better fruits, even in a country noted for its delicious pineapples and incomparable mangosteens.

There are doubtless many other lines along which the gardens at Buitenzorg have improved. The selection of sugar cane seedlings, the hybridizing of coffee, the establishment of a new zoological museum to be under the management of Dr. Konigsberger and to contain mounted specimens of all the many interesting animals and cases of the injurious and biologically interesting insects of the archipelago, were all propositions under consideration at the time of my short visit in January. I am thoroughly convinced that to any one who expects to make a thorough study of tropical plants a visit to this Botanical Institute will be of the greatest advantage. Its opportunities surpass those of any other in the world.— DAVID G. FAIRCHILD, *Department of Agriculture.*

THE CARDINAL PRINCIPLES OF MORPHOLOGY.[2]

ALTHOUGH botany has made remarkable advances in America during the past few years, there is still one phase in which it remains singularly backward, namely, in its treatment of the morphology of the higher plants. There still prevails among us, with little modification, the old formal idealistic morphology, whose founder was Goethe, and whose great exponent in this country was Gray; while we give scant consideration to the newer natural realistic system, now more or less fully accepted elsewhere, and recently given greater extension by its leading advocate, Goebel. We have, it is true, some literature of the newer morphology, of which an example is Professor Barnes' discussion of the Flower in the *Cyclopedia of American Horticulture*, while the treatment of the homologies of the higher with the lower plants is good in most of our recent text-books; but from these there is every gradation backward. Happily the newer standpoint is becoming generally accessible to American students through the publication of Goebel's *Organographie der Pflanzen* (Jena, Fischer, 1898–1900), now being translated into English under the title *Organography of Plants* (Part I, Oxford, Clarendon Press, 1900). In the present paper I propose to summarize what seem to me the principles upon which the newer morphology is based.

The difference between the idealistic and the realistic morphology, while partly one of fact, is mainly one of point of view. The idealistic system is based principally upon comparative anatomy; it concentrates attention upon the steps, or stages, in morphological changes, or metamorphoses, but is largely indifferent as to the processes, or mechanics, by which the metamorphoses have been brought about; metamorphosis is therefore to it chiefly a phylogenetic operation, whose exact ontogenetic basis is of secondary consequence. The realistic system, while giving great weight to comparative anatomy, lays especial emphasis upon the testimony of embryology, particularly seeking the actual ontogenetic origin and development, the mechanics, of metamorphoses, only through which, it maintains, can the true nature of metamorphosis be understood; metamorphosis is, therefore, to it primarily an ontogenetic process which later and secondarily becomes fixed in the phylogeny. The former, the idealistic or phylogenetic system, predisposes one to generalized and abstract conceptions, while the latter, the realistic or

[2] Read before the Society for Plant Morphology and Physiology, Johns Hopkins meeting, December 28, 1900.

ontogenetic, leads to more definite and concrete conclusions. Both views equally assume the fact of evolution in the phylogenetic fixation of metamorphoses, but both are equally independent of the exact method (the dynamics) by which that evolution is brought about, whether this be through natural selection involving the whole organism, or through germinal selection, or through organic selection, or through the accumulation of transmitted effects of individual irritable responses, or through some other method still unknown. The realistic system, however, brings us more nearly face to face with the problems of the dynamics of evolution than does the idealistic system.

We pass next to an attempt to deduce the fundamental or cardinal principles of morphology. Of these, some are not peculiar to morphology alone, but belong equally to other phases of evolution and adaptation, while others are especially characteristic of morphology.

FIRST, the principle of *continuity of origin*, that is, no functional structure ever arises *de novo*, but only from the modification of a pre-existing structure, which in turn arose from a still earlier, and so on backward through a longer or shorter chain ending only in the original protoplasmic variation, or in whatever it is which does lie at the beginning of specialization. This principle is axiomatic for both systems of morphology.

SECOND, the principle of *opportunism*, that is, the direction taken in metamorphosis is not determined by obedience to any pre-formed plan, but, except for the influence of the inertia of the heredity of the particular part, follows the factors potent at the moment. Heredity of itself cannot impose any plan, for it is but the summation of the interaction of past experiences with original properties. Theoretically this principle should be as acceptable to the idealistic as to the realistic morphology. In practice, however, the idealistic conception of metamorphosis as a whole is that of a play of a very few highly plastic "members," which, however much they may vary and combine, retain a sort of fundamental immutability of nature, as witness the efforts to explain all parts of the flower in terms of "leaves" and "stem," and the use of the expression "disguised" often applied to metamorphosed parts. There is thus imposed upon metamorphosis a sort of ideal plan, a plan implying that modification keeps within certain limits, determined by the possibilities of permutations and combinations of those members. The realistic morphology is bound by no such conception,

for the members are unlimited in number and have no ideal nature or limitations to be consulted.

THIRD, the principal of *functional domination* in metamorphosis, that is, it is function which takes the lead and structure follows. It is of course true that function and structure are reciprocally related; there are cases where structure determines function; there are other cases in which non-functional factors, especially an aggregation of them, may outweigh a functional factor; nevertheless, it must be true that in a broad way it is function which determines structure, function often hampered, and even sometimes thwarted by other influences it is true, but function dominant in the long run. If this is not true, adaptation is but an accident if not a myth, and our whole idea of it but a vain vaporing of the imagination. This principle in general is necessary to both systems of morphology, but it is more prominent in realistic than in idealistic discussions.

FOURTH, the principle of *indeterminate anatomical plasticity*, that is, in all anatomical characters (size, shape, number, position, color, cellular texture) plant-organs, or, if one pleases, plant-members, are not limited by anything in their morphological nature, but, under proper influence, may be led to wax and wane indefinitely in any of these respects. Of course this plasticity is hampered by innumerable practical considerations, and by many hereditary "tendencies," and many generations may be (though they are by no means always) necessary to produce a marked and permanent result; but the point is that limitations to anatomical plasticity do not come from the morphological nature of the part concerned. The principle may also be stated thus, that there is no causal relationship whatever between morphological nature and anatomical structure; stipules are usually smaller than the leaves they accompany and markedly different in form; yet they may become as large as the leaves and indistinguishable from them (as in Galium), or much larger, as in some Leguminosae; there is obviously therefore nothing in the nature of a stipule as such to limit its size or shape; that it is usually smaller than its leaf is a purely functional and non-morphological matter. So, stems may lengthen immensely as in climbers or shorten to apparent disappearance as in rosette-plants, and so on with all other parts. This principle is equally true for both systems of morphology, and is perhaps the most clearly recognized of them all.

FIFTH, the principle of *metamorphosis along lines of least resistance*,

closely related to opportunism mentioned above. This means that when, through a change in some condition of the environment, the necessity arises for the performance of a new function, it will be assumed by the part which happens at the moment to be most available for that purpose, regardless of its morphological nature, either because that part happens to have already a structure most nearly answering to the demands of the new function, or because it happens to be set free from its former function by change of habit, or because of some other non-morphological reason. It is due to the operation of this principle that structures of the most different morphological origin may come to serve the same function, and correlatively, structures of the same morphological origin may come to serve the most different uses. The genus Pereskia, in the Cactaceae, includes mesophytic climbers with true broad leaves, from which all gradations in reduction of leaves and condensation of stem may be traced even to the typical desert forms of Cereus. Now, one division of Cereus returns to a life in the woods, where the demand for an increase of green surface is felt; no attempt, however, is made to restore the old leaves (now reduced to tiny scales), but the stem enlarges and branches, while the vertical ribs, developed during the desert habit, are expanded farther and made to function as leaves. As the mesophytic habit becomes more extreme, the ribs become larger in size and fewer in number until finally, in Phyllocactus, but two remain, and these become so flattened and arranged in such a manner on the branch that they form a physiological and anatomical leaf. Here we have a case, indubitable because abundant intermediate steps persist, in which a physiological leaf has been developed from a morphological stem, purely by following the line of easiest accomplishment, or least resistance, at the moment; no single step is in itself remarkable, but the sum total yields a very remarkable result. This principle is, of course, equally applicable to both systems of morphology.

SIXTH, the principle of *metamorphosis by transformation*, as contrasted with metamorphosis by differentiation, which means that when, in response to any influence, a new function and hence structure (function-structure) is assumed by any part, this always comes about, both ontogenetically and phylogenetically, through the transformation or alteration of a previously existing function-structure in that part, and never through the differentiation of a new function-structure out of a previously functionally-indifferent or unspecialized structure. In

other words, since all parts of the plant actually are organs (that is have some meaning in the life of the plant), new organs can arise only by the transformation of previously existing ones. We face here a sharp contrast in the two systems of morphology. The idealistic system, laying as it does great stress upon members in distinction from organs, comes to regard these members as if they had a real existence, forgetting that the conception of the member is a pure abstraction of the mind, a sort of mental composite photograph, with no objective equivalent, and that members apart from organs do not really exist. The conception of the member as an entity having once been formed, metamorphosis is naturally regarded as the differentiation of an organ out of a member, and this not only phylogenetically but also ontogenetically; so that by those who carry the idealistic system into ontogeny at all, the ontogenetic unfolding of any organ is viewed as a differentiation from primordia (Anlagen) which, after the analogy of the members, are supposed to be indifferent in their nature. Not only, however, is this view untenable upon philosophical grounds, but it is negatived by the fact that in cases where metamorphoses are experimentally brought about, embryology shows that the process is actually one of transformation of one function-structure into another, and not of differentiation of a function-structure out of a neutral or indifferent primordium (Anlage). But this subject is so clearly treated by Goebel in the Introduction to his *Organography* that it needs no further consideration here. How these, in their origin purely ontogenetic, metamorphoses become fixed in the phylogeny, is an entirely separate question, the solution or non-solution of which does not in the least affect the truth or non-truth of this principle. The idealistic conception, that an organ is formed by differentiation from a member, implies as a corollary that each organ is but one step, so to speak, from a member, and should be readily reducible to it; hence arise the attempts to explain all parts of such complex and specialized structures as epigynous flowers in terms of leaf and stem, necessitating the adnate calyx theory with its requirement of extraordinary assumptions as to growing together of parts, etc., entirely unsupported by the facts of development.

SEVENTH, the principle of *gradation in morphological membership*, involving the existence of degrees of morphological independence, culminating in the attainment of full morphological membership with full independence. Or, it may be expressed thus: in the progressive

development of metamorphoses, difference of degree passes over gradually into difference of kind. This principle, in my opinion the most fundamental in morphology, marks far more sharply than any other the difference between the two systems, for it is fundamental to the realistic, but inconsistent with the idealistic conception. It means that, as an organ gradually acquires a new function-structure, and the old function-structure is gradually lost, new powers of variation, adaptation, etc., are acquired which become more and more independent of those formerly possessed by the organ, until finally the change may become so complete that the new organ not only acts itself quite independently of its old nature, but becomes a new starting point or center of metamorphosis, that is, it becomes a new morphological member. New metamorphoses, however, are not confined for their starting-point to the full members, but may originate from any of the points along the lines of gradation. Hence, not only may any organ become a member, but the members grade into one another indefinitely and any of the gradations may act as members. This is in great contrast with the conception of the idealistic system as applied to the higher plants, for that conception not only limits the number of the members to a very few (at the extreme root, stem, leaf, plant hair, exclusive of the sporangia), but practically views these as sharply distinct, not recognizing intermediate transition from which new metamorphoses may originate. In fact the idealistic morphology, while admitting the original evolutionary origin of its members, ignores evolution in their subsequent interrelationships; it views its members much as species were viewed in pre-evolutionary times, while the realistic system applies the idea of evolution throughout. The idealistic system views the morphological members much as a chemist does his elements, which may combine in many ways, but retain their identity throughout; the realistic system regards them more as a physicist does the colors of a spectrum, as a series of stages in a graded sequence of phenomena.

As an example of an organ which has attained to full morphological membership and independence we may consider the spines in the Cactaceae. Research has shown much evidence for the belief that these structures have arisen by the metamorphosis of leaves; the only competing theory is that they are a form of "emergences;" no investigator has ever seriously supposed they were anything else. Now, despite much long-continued observation and special search, no one has ever

been able to find transitions between these spines and either leaves or emergences (except in the case of a few monstrosities which may have another meaning), nor have repeated experiments succeeded in making the spines return to leaves or emergences. Now, the cactus spines are immensely variable, becoming very big and hard on the one hand, or weak and small even to disappearance on the other, cylindrical and erect to ribbon-like and contorted, plain or variously ornamented, smooth or beautifully plumed or fringed, curved into hooks useful for climbing, or altered entirely into nectaries. But, throughout all of these variations it is distinctly and unquestionably a spine, an anatomical spine that is varying, and not a disguised leaf or emergence. We must conclude from all these grounds that the cactus spine has attained to full morphological membership, is itself a member, a center of modification and metamorphosis. The mamillae, or tubercles, in the same family, originate by a union of the leaf-base and its axillary bud, but the identity of these two parts becomes completely lost in the new identity of the tubercle, which becomes a member and acts as such through many genera. The ribs in Cactaceae arise by the running together of vertical lines of tubercles; once formed, however, they pay little attention to their mode of origin but proceed to act as independent members, as one may clearly see when he considers their performances (particularly their independent increase or reduction in number) in the development of the cladophylls of Phyllocactus already cited in this paper. In some genera, however, particularly Echinocactus, the ribs have not attained to full independence, for they occasionally revert to lines of tubercles. But we need not go so far afield for our illustrations of the attainment of independent membership, for the members commonly accepted by the idealistic system (root, stem, and leaf) illustrate it perfectly. Most of us no doubt believe that the present-day foliage leaf and stem arose through the sterilization of sporogenous tissue in a primitive very simple sporophyte; but whether we believe it or not does not matter for our present purpose, for we must believe, if we accept evolution at all, that leaf and stem have become specialized out of a simpler structure which did not show those distinct parts. All morphologists accept the foliage leaf and its stem as of full morphological membership and independence, to such a degree indeed that they stand in most minds as the very types of morphological members. Now, in their case, even the idealists never attempt to interpret their morphological behavior in the light of the nature they

had before they were leaf and stem. Why, then, does the idealistic morphology insist, for example, upon reducing everything (excepting the sporangia) in a highly specialized flower to the categories of leaf and stem? In fact, the flower has been so long an independent organ that it has had time to progress far toward independent morphological membership, as witness its ability to suppress circles, to alter the number of their parts, and to rearrange their phyllotaxy quite independently of any actions performed by leaves on a stem. Moreover, various parts of the flower (in some flowers, not in all) have become more or less independent members, as we may clearly see in those which are epigynous. The ovary of such a flower, for example, unquestionably originated in sporophyllary leaves standing upon a conical receptacle, precisely as in numberless flowers today; gradually, however, as embryology proves, the formation of the ovarian cavity was given up by the carpels, and assumed by the receptacle, which grew up in the form of a cup carrying the other parts upon its rim, while the carpels finally came to form simply a roof over the cavity. But, and here is a crucial point, it must not be supposed that during this process the receptacle and carpels retained their old carpel and receptacle nature (much less their "stem" and their "leaf" nature); on the contrary, the new kind of ovary acquired an identity and a character of its own, and in that new identity and character the old identity and character of receptacle and carpel gradually melted away, and lost their distinctness, so that such an ovary has become a new member and is not simply a compound of receptacle and carpel. It is useless, therefore, to expect that such an ovary will build placentae, partitions, style, or stigma according to the rules in vogue with ordinary receptacle and carpel, and useless also to discuss whether in such an ovary the cavity is lined with carpel or not, for the ovarian wall is no longer either receptacle or carpel or both, it is ovarian wall; carpel and receptacle have not fused to form it; their tissue has melted away, so to speak, into the tissue which does form it. For simplicity I here treat this attainment of membership by such an ovary as if it were complete, though in fact it is not so in any ovary known to me, for in all of them some features of both carpel and receptacle may be traced, especially at top and bottom of the ovary. So also, with other parts of the flower; the placenta, which originated in the manner still shown by many flowers, as swollen edges of carpels, has become independent of its carpellary origin in many flowers, as in those with free central placenta, where no trace of

the old leaf nature may be found in its entire ontogeny. The tube of gamopetalous flowers is another structure which in some cases has attained to approximate independence, and the style and stigma yet another. All of these parts may become centers of independent (though usually limited) metamorphosis, altering in size, shape, number, building new structures (as the corona) all independently of anything they did before they acquired their present more or less completely independent membership. It is so with the ovule, originating in a macrosporangium, but now an independent member. The same is true of the embryo-sac, which, originating unquestionably as a germinated macrospore, has, after a long history, become a new member with a high, though not a complete independence. Some of its features are to be explained as a persistence of its ancient nature, but it is useless to attempt to interpret all its actions upon that basis, for it does some new things upon its own account — as a new member, the embryo-sac. To return for a moment to the flower as a whole, it is important to notice that the study of its morphology is in one sense complex and difficult, partly because it is a composite structure with various degrees of independence in its component parts, partly because its development in different families has been so independent that it has given rise to homoblastic rather than homogenetic homologies. Hence it is impossible to make distinct categories of members applying to all flowers, but each group must be considered by itself, a feature indeed which applies not to the flower alone but to the vegetative parts as well. Hence we must in theory recognize as potential members all organs, one may even say all recognizable parts, although in practice it is needful to take account for the most part only of those most conspicuous and distinct.

The realistic system, with its infinite gradations and limitless possibilities, is much harder to grasp and to apply, and is less pleasing to teach than the idealistic system, with its few distinct categories and their involved limitations. But it is truer to nature, more stimulating to research, and more replete with promise of great results.— W. F. GANONG, *Smith College, Northampton, Mass.*

CURRENT LITERATURE.

BOOK REVIEWS.

A Californian manual.[1]

THIS manual by Professor Jepson deserves more than a passing mention, for in a certain sense it is constructed on new lines. The average manual is chiefly a compilation of scattered literature checked by more or less herbarium study. The result is merely an approximation to the facts and never quite satisfactory to the field student. Professor Jepson has met his plants in the field and has described them as they live. He has recognized literature so far as it fits his material, but has not allowed it to bias or handicap him. As a consequence, the descriptions are remarkably fresh and telling, and have no flavor of stereotyped diagnoses. Not only is the wonderfully diverse Californian flora set forth, but numerous ecological notes suggest the factors that lie behind the diversities. Repeated attention is called to the variations in vegetative characters which a single species may undergo in different situations. The following statements from the preface are worthy of quotation, since they are of general application:

1. Near the ocean a species is often more depressed or condensed than in the interior, and more fleshy.

2. In swamps or wet soils the plant tends to become succulent and of ranker growth, and also glabrous.

3. In valley soils the growth is commonly much more rank than elsewhere.

4. On hilltops plants tend to become dwarf and acaulescent; often far more pubescent also.

5. In saline or subsaline soil the stems and foliage in many species are far more vigorous and the flowers larger than on stiff clays or adobes.

6. In the shady woods leaves become thinner and larger, often conspicuously so.

7. At high altitudes the flowers are larger in proportion to stature and brighter in color.

Such facts are known to the ecologist, but it seems hard to get the taxonomist to give them due weight. The region covered lies west of the Sacramento and San Joaquin rivers, south of the counties of Mendocino and Colusa, and north of the Pajare river and Pacheo pass. Several such manuals will be needed to present the flora of California, and it is daily becoming more evident that no one is competent to prepare them who has not lived among the plants. The numerous analytical keys are prepared with special

[1] JEPSON, WILLIS LINN: A flora of western middle California. 8vo. pp. iv + 625. Berkeley, California: Encina Publishing Company. April 16, 1901. $2.50.

care, and the verbiage of pedantry has been eliminated. A number of new species are described, but from the statements made the field seems to be white for the harvest. Professor Jepson is to be congratulated upon producing a useful, rational, and modern manual.—J. M. C.

The Cyclopedia of American Horticulture.

The third volume of Bailey's *Cyclopedia of American Horticulture* has just come from the press of the Macmillan Company. It includes the letters N–Q.[2] Aside from the articles on important genera, among which the most noteworthy are those on Nepenthes, Nymphaea, Odontoglossum, Oncidium, Opuntia, Pinus, Prunus, Pyrus, and Quercus, the following articles are of special interest. The botanical treatment of *Orchids* is by H. Hasselbring, the culture of orchids by Robert M. Grey, with a general introduction by the editors. On the *Peach*, the general article is written by Professor Bailey, peach culture in the south is treated by J. H. Hale, peach culture in the far north (northern Vermont) by J. T. Macomber, the Michigan peach industry by R. Morrill, peach culture in Delaware by Charles Wright, the peach in California by H. Culbertson. Professors Bailey and T. T. Lyon contribute a general article on *Pear*, C. L. Watrous writes about pears on the northern plains, E. J. Wickson on the pear in California, John S. Collins on the Kieffer pear, L. T. Yeomans on dwarf pears, and George T. Powell on pears for export. The horticultural capabilities of the *Philippines* are described by F. E. Gannett. A somewhat unexpected article is the one on *Horticultural photography* by J. Horace McFarland. It ought to be very helpful and to result in the great improvement of the illustrations in our experiment station reports and other similar publications. A compact article upon the general *Physiology* of plants is contributed by Dr. B. M. Duggar. The article on *Plant breeding* by Mr. H. J. Webber will attract attention. The principles of the art are well set forth, but it is unfortunate that he unnecessarily insists on calling stamens and pistils the male and female organs of plants. On the *Plum* Professor Bailey writes the general article, Professor F. A. Waugh discusses the cultivation of native plums, and Mr. A. V. Stubenrauch gives an account of the plum in California. The article on *Pomology* is naturally handled by the editor, an appendix on Russian fruits being contributed by John Craig. The work maintains the high standard of the preceding volumes.[3] —C. R. B.

[2] BAILEY, L. H.: Cyclopedia of American Horticulture, comprising suggestions for cultivation of horticultural plants, descriptions of the species of fruits, vegetables, flowers, and ornamental plants sold in the United States and Canada, together with geographical and biographical sketches. Vol. III. N–Q. 4to, pp. xv+1055–1486, *figs. 1454–2059, pls. 20–29*. New York: The Macmillan Company. 1900. $5.

[3] Bot. Gaz. 29: 282; 30: 277. 1900.

MINOR NOTICES.

DR. G. N. BEST has revised the North American species of Heterocladium[4] recognizing four species, of which two, *H. Macouni* and *H. heteropterioides* are new. Three Kindbergian species are in the "doubtful or excluded" list. —C. R. B.

EMMA J. COLE[5] has published a catalogue of the native vascular plants growing in the vicinity of Grand Rapids, Michigan. The ntroduction presents the general physiographic and ecologic features of the region, and in the list all known stations are carefully recorded. The number of native plants recorded is 1111, of introduced plants 176.—J. M. C.

V. K. CHESNUT and E. V. WILCOX have published a valuable preliminary report (Bull. 26, Div. of Bot., U. S. Dept. Agric.) of their investigation of the stock-poisoning plants of Montana. It contains not only a detailed account of their observations and experiments, but also summaries of symptoms and remedies. The most important plants poisonous to stock in Montana are the death camas (*Zygadenus venenosus*), tall larkspur (*Delphinium glaucum*), purple larkspur (*D. bicolor*), Wyoming water hemlock (*Cicuta occidentalis*), white loco weed (*Aragallus spicatus*), and various lupines (*Lupinus* spp.).—J. M. C.

THE FIRST FASCICLE of what promises to be a very excellent treatise on botany by Bonnier and DuSablon has just been published.[6] The work is intended specially for advanced students in the universities and schools of medicine, pharmacy and agriculture. The first section discusses such general matters as the characters of plants, the members of the plant body, the large divisions of plants, the cell and the tissues. The second section, entitled the morphology of angiosperms, concerns itself with the primary and secondary structure of stamens, leaves, and roots. The illustrations are fresh and in the main excellent, though the anatomical ones are better than those representing external features. We reserve further notice of this work until its completion.—C. R. B.

WILLIAM R. MAXON[7] has published a very useful list of the pteridophytes of North America north of Mexico. Eaton's *Ferns of North America* and

[4] Bull. Torr. Bot. Club **28**: 123–131. *pls. 13, 14.* 1901.

[5] Grand Rapids flora, a catalogue of the flowering plants and ferns growing without cultivation in the vicinity of Grand Rapids, Michigan. 8vo. pp. xxii + 170. Grand Rapids: Lyon, Kymer & Palmer Company. 1901. $1.00.

[6] BONNIER, GASTON, and DUSABLON, LECLERC: Cours de botanique; anatomie; physiologie; classification; applications agricoles, industrielles, médicales; morphologie expérimentale; géographie botanique; paléontologie; historique; à l'usage des élèves des universités, des écoles de médecin et de pharmacie, et des écoles d'agriculture. Vol. I, part 1. 8vo, pp. 384, *figs. 553*. Paris: Paul Dupont. 1901. Complete in 6 parts. 25 fr. Each part singly 6 fr.

[7] A list of the ferns and fern allies of North America north of Mexico, with principal synonyms and distribution. Proc. U. S. Nat. Museum **23**: 619–651. 1901.

Underwood's *Our native ferns and their allies* have been the only works of sufficient scope to include this territory. The former is more than twenty years old, and the latter is essentially a popular treatise in which there are no citations. As a consequence, a list of the known ferns and their synonymy has been a *desideratum* for some time, and this Mr. Maxon has supplied. Besides his careful bibliographic work, the author has included the recorded geographic range of each species, thus adding very materially to the value of the list. What may be called the Underwood nomenclature and sequence are followed.—J. M. C.

A LABORATORY MANUAL[8] has recently been published by F. E. Clements and I. S. Cutter. It is of special interest as being "an authoritative expression from the Department of Botany of the University of Nebraska upon the kind and amount of elementary botany that should be taught in the accredited schools and colleges of the state." The directions for work are clear and compact, and based upon long experience in handling the material. Granted that such material is best suited to high-school courses, no exception can be taken to the way in which it is presented. A question might be raised, however, as to the "kind of elementary botany" that this book calls for. To start high-school pupils with a short course in histology is probably not commended now as much as formerly. The part devoted to structure and classification would seem to be a more fitting introduction to the use of plant material. A good set of physiological experiments is also included, and it is interesting to note that a certain amount of work in ecology is called for. The book must be of great service to the schools of Nebraska in so far as it relates them to the work of the University.—J. M. C.

THE PROCEEDINGS of the twenty-first meeting of the Society for Promotion of Agricultural Science, recently distributed, form a volume of 183 pages, containing articles of botanical interest. The president's chair was occupied by a botanist, W. J. Beal, of Michigan, but the annual address dealt chiefly with matters of general interest to the society. A "syllabus for a short course on grasses and other forage plants" by the same person is of decided pedagogical value. "The development of a tomato hybrid" by W. M. Munson is an account of the production of a desirable hybrid variety by crossing the common and the currant tomato. "The chemical function of certain soil bacteria" by Frederick D. Chester, "Seven years of experiments with bush beans" by Byron D. Halsted, "The value of willows in retaining the banks of streams" by W. W. Rowlee, "The course in cryptogamic botany" by L. H. Pammel, "The weedy plants of Iowa," also by Mr. Pammel, contain botanical matter with practical applications of the facts. H. L. Bolley corrects some errors of microscopic interpretation occurring in his

[8] A laboratory manual of high school botany. 8vo. pp. 123. Lincoln, Nebraska: The University Publishing Company. 1900.

bulletin no. 27 from the N. Dakota Experiment Station. Two very interesting articles are "Twenty years progress in pathology" by B. T. Galloway, and "The botanic garden as an aid to agriculture" by William Trelease.—J. C. ARTHUR.

A NEW LABORATORY GUIDE for bacteriology by Mr. W. D. Frost, of the University of Wisconsin, is a convenient combination of directions for experiments, blank pages, charts, and outline drawings in which results may be recorded, together with some general information.[9]

The first part of the book is devoted to general bacteriology with the usual description of technique and laboratory methods. The medical part of the book is more complete than usual for an elementary text book.

General information is given in the form of brief notes wherever a germ is mentioned for study, relating its source, time of isolation and discoverer, with references to the original and other descriptions. A chapter on taxonomy includes Chester's scheme of nomenclature of cultural characters and Migula's valuable classification of bacteria.

The most striking features of the book are the well-outlined and systematic arrangement of material, and the unusual and deserved attention given to one of the most important problems in the study of bacteria today, the effect of environmental action. The chart blanks are excellently designed for the record of the numerous physiological and morphological characters of a culture under study. A useful supplement to these detailed record blanks would be a few charts such as those recommended by Fuller for recording definite positive and negative reactions in comparative form. The book as it stands, however, is very complete and will be welcomed in many laboratories.—MARY HEFFERAN.

NOTES FOR STUDENTS

THE great prevalence of potato blight (*Phytophthora infestans*) in the state of Washington for the past two years has led to the publication of a bulletin[10] on the subject by the Agricultural Experiment Station, based on experiments made at the Puyallup station. Bordeaux mixture applied before the disease began to be apparent and again after about two weeks was found to decrease materially the injury from the disease.—ERNST A. BESSEY.

PROFESSOR CONWAY MACMILLAN has been studying the growth periodicity of the potato tuber[11] by the method described in this journal (16: 149. 1891) which he has improved upon by employing a second wheel to magnify

[9] FROST, WILLIAM DODGE: A laboratory guide in elementary bacteriology. 4to pp. viii + 200. Published by the author. Madison, Wis. 1901.

[10] BRODIE, DAVID A.: Potato blight and its treatment. Bull. 46, Washington Agricultural Experiment Station, pp. 15, *figs. 5*. 1901. Pullman, Washington.

[11] Bull. Minn. Acad. Nat. Sci., 3: 355-362. 1901.

more the tracing of the auxanometer. He finds the increase in diameter rhythmic, with maxima once or twice or oftener in 24 hours, followed by minima when growth ceases or nearly so. There are indications of a grand period, and some connection between the periodic growth of the aerial parts and tubers.—C. R. B.

MISS MATHILDE GOLDFLUS[12] finds that chlorophyll not only persists under the cork of many branches, but that it is present in the medullary rays, in the pith, and is even formed in the cortex of trunks of trees at the bottom of the crevices in a ridgy bark, as in Quercus and Robinia. Indeed it may develop in any living tissues. Photosynthesis by this chlorophyll is active, more than counterbalancing the production of CO_2 in respiration, though no quantitative determinations seem to have been made. Inasmuch as the area exposed by branches is considerable, and as photosynthesis continues in winter, it is evident that it is of considerable importance to the plant. Miss Goldflus and Mr. Miyake[13] have thus called attention to hitherto overlooked activity of the chloroplasts.—C. R. B.

S. KUSANO (Bot. Mag. Tokyo **15**: 42–46. 1901) has published a short account of the parasitism of *Buckleya Quadriala*, one of the Santalaceae of Japan. Its haustoria apparently attack the roots of almost any plant, as witnessed by the artificial cultures made. As a result of the attack the activity of the cambium of the host-root seems to be much increased, since a transverse section of that part shows the greatest diameter of wood and cortex. "If the age of a haustorium may be estimated from the annual rings of the host-root which overlie the sucking process, it is safe to conclude that the same organ of Buckleya can maintain its activity during fifteen years, and probably longer." The author found no difficulty in cultivating these green parasites by sowing the seeds in the same pots with the seeds of other plants which might serve as hosts.—J. M. C.

IN A RECENT PAPER Noll[14] takes up again the much discussed subject of polarity among the marine algae. Beginning with the statement that in *Bryopsis muscosa*, on which he worked, the polarity is as pronounced as in Pinus, he states as a result of his experiments that very few of his plants reversed their root and shoot poles when inverted. By measurements and dates he ascertained that the young and actively growing plants were so strongly polarized as to resume the original manner of growth; that only the older more slowly growing forms succumbed to the force of external conditions and turn root into shoot and shoot into root. Hence the inherited polar-

[12] Revue gén. de Bot. **13**: 49–92. 1901.

[13] Bot. Mag. Tokyo. **14**: 44. 1900. See Bot. Gaz. **30**: 141. 1900.

[14] On reversion experiments on Bryopsis, with remarks on energids. Ber. d. deut. bot. Gesell. **18**: 444–451. 1900.

ization is lost with age. These results agree with those of Winkler of an earlier date. To the definition of an "energid," as given by Sachs, Noll takes exception, and calls the Siphoneae "single but multinucleate energids," laying stress rather on the *Hautschicht* than on the nucleus with its dominated mass of protoplasm. He therefore defines the energid as a "one or many-nucleate plasmatic body enclosed in a definite wall."— PHILIP GRAEME WRIGHTSON.

"A rhizomorphic root-rot of fruit trees"[15] is the title of a recent bulletin of the Oklahoma Agricultural Experiment Station. For a number of years a serious root trouble, especially of the apple, has been attracting the attention of fruit growers and botanists in Missouri, Illinois, Oklahoma, and Texas, as well as in other regions. This has been shown by von Schrenk and others to be caused, in all probability, by a hitherto unidentified rhizomorph-producing fungus. In the present bulletin, based upon work taken up since last June, the disease is shown to attack other trees also than merely fruit trees, and is ascribed to a species of Clitocybe which is described as new under the name *C. parasitica*. This was found at the base of many diseased trees and was accordingly considered to be the cause of the disease. Most of the bulletin is given up to a discussion of previous work on diseases of trees caused by agarics, to a host index of these fungi as they affect trees, and to a long bibliography. The discussion of the disease under consideration is really limited to four or five pages.— ERNST A. BESSEY.

THE SUBJECT of asparagus rust is one that continues to attract attention. A recent bulletin by F. A. Sirrine[16] discusses the disease and its treatment in New York. All the stages of the rust are found to occur in the state. The variations in the distribution of the disease ascribed by some investigators to soil conditions seem rather to be due to the occurrence or non-occurrence of dews or dense fogs which furnish the moisture necessary for the germination of the spores. The measures usually recommended in combating this disease, viz., cutting and burning the affected fields early in the fall, are shown to be injurious to the plants and not of appreciable value in reducing the amount of rust next year. Using a specially devised spraying machine, which enabled the operators to wet all parts of the plants thoroughly, was found in two years trials under unfavorable conditions to effect a gain in the crop of 69.5 per cent. for the first year and of 47.8 per cent. for the second year. The best results were obtained with a Bordeaux mixture to which was added a solution of

[15] WILCOX, E. MEAD: A rhizomorphic root-rot of fruit trees. Bulletin 49, Oklahoma Agricultural Fxperiment Station. p. 32. *pls. 11*. February 1901. Stillwater, Oklahoma.

[16] SIRRINE, F. A.: Spraying for asparagus rust. I. Tests with resin-Bordeaux mixture. II. The Downs power asparagus sprayer. N. Y. Agric. Exper. St. Bull. no. 188, pp. 233–276. December 1900.

resin. Spraying was not found to be profitable where the disease had so weakened the plants that they gave less than one third of the normal crop.—ERNST A. BESSEY.

ATTENTION is called to a group of fungus diseases hitherto almost unnoticed in this country in a joint bulletin by B. M. Duggar and F. C. Stewart entitled "The sterile fungus Rhizoctonia as a cause of plant diseases in America."[17] The genus Rhizoctonia is a so-called form genus, *i. e.*, it consists of fungi whose spore forms are unknown but which agree generally in their vegetative characters. The fungus is characterized by a peculiar method of branching of the hyphae, by the formation of sclerotia, and by its usually parasitic habit on roots and underground parts of plants. The authors find that this fungus is present on many different hosts, including among the most important the potato, beet, bean, carnation, lettuce, and radish. Whether the same species affects all these plants still remains to be determined by cross-inoculations. In most if not all of the plants mentioned, the fungus causes a severe root-rot, which often results in the death of the host. That the fungus is the cause of the disease was proved in some of the cases by repeated inoculations with pure cultures. As the paper is in a measure only preliminary the discussion of the special morphology and physiology as well as of the taxonomy and relation to European forms is reserved for a later paper, in which will also be taken up the results of inoculation experiments. —ERNST A. BESSEY.

PROFESSOR G. J. PEIRCE[18] has published some interesting studies on *Sequoia sempervirens*, chiefly in connection with the development of suckers, a very unusual habit among Gymnosperms. The claim is made that reforesting is entirely possible if suckers and seedlings are not destroyed by fire. In the tendency of the suckers to fasciation the author confirms Frank's view that it is in consequence of an excess of food substances in available form. The most prominent feature of the paper, however, is the discussion of the albinism of certain suckers. These are by no means uncommon, and they differ decidedly in rate of growth, in resistance to cold, in leaf structure, etc., from green suckers. The author thinks that the albinism is due to the fact that the leaves form and attain nearly or quite full size when there is insufficient warmth for the formation of the chromoplasts and the chlorophyll, though enough for growth. One interesting feature of the albinism is that when a sucker begins white it always remains so, no matter how favorable

[17] DUGGAR, B. M. and STEWART, F. C.: The sterile fungus Rhizoctonia as a cause of plant diseases in America. Bull. 186, Cornell University Agricultural Experiment Station, Ithaca, N. Y. Bull. 186, New York Agricultural Experiment Station, Geneva, N. Y., p. 28, *figs. 9*. January 1901.

[18] Studies on the coast redwood (*Sequoia sempervirens* Endl.). Proc. Calif. Acad. Sci. III. Bot. **2**: 83–106. *pl. 14*. 1901.

the later conditions may be for the development of a green sucker. The author suggests as an explanation that the sucker is in unbroken connection with an abundant food supply, and that there is not the stimulus of need for a later production of chromoplasts and chlorophyll. The contribution closes with an interesting discussion of parasitism and heredity from the standpoint of white suckers. Attention is called to the fact that in this case absolute parasitism in habit and structure is developed by the environment in a single generation from a long line of independent plants It would seem to the author, therefore, that the influence of heredity is less powerful than the power of reaction to certain immediate stimuli, and he closes as follows: "May not this always be the case? May it not be that what we call heredity is really the response to similar stimuli and combinations of stimuli occurring in orderly succession in the course of nature?"—J. M. C.

BOTANICAL ARTICLES in annual reports of Agricultural Experiment stations, not heretofore noticed in these pages, are as follows: Report of the New York station for 1900 contains reprints, with admirable plates, of bulletins 161, 162, 163, 164, 167, 169, and 170, all of much interest to students of plant diseases and of some other topics. Report of the Wisconsin station for 1900 contains a number of original articles. S. M. Babcock and H. L. Russell discuss the "Causes operative in the production of silage," and arrive at the conclusions that the presence of bacteria is unessential and even deleterious, that the chief action is intramolecular respiration of the plant cells, producing carbon dioxid and organic acids in proportion to the length of time the cells remain alive and active, and that the aroma is due to the action of enzyms. These are unexpected and important results. The same authors describe with illustrations an excellent "Closed circuit respiration apparatus," which would be most useful in a laboratory of physiology. E. S. Goff reports on "Investigations of flower buds" and concludes that "in favorable seasons of flower formation, many of the buds formed that season, and nearly all those formed the preceding two seasons, that have not already flowered, will become flower-buds; an excessive apple crop results, which is necessarily followed by a light one, because the supply of reserve buds is exhausted." The same writer treats of "The resumption of root growth in spring" and "The effects of continued use of immature seed;" while F. Cranefield writes upon "Duration of the growth period in fruit trees." In the 7th Report (1899) of the Wyoming station are excellent "Alkali studies," dealing with the germination and growth of seeds, by B. C. Buffum and E. E. Slosson, and in the 10th Report (1900) Aven Nelson gives a list of "The cryptogams of Wyoming," including the algae, fungi, and mosses. Other botanical articles in these reports have previously been published as bulletins. The report of the botanists, George E. Stone and Ralph E. Smith, in the 11th Report of the Hatch (Mass.) station deals with a variety of fungal and

physiological disorders of plants. In the 12th Report the same writers discuss a number of fungous diseases, especially tracing a relation between the abundance of asparagus rust and the physical character of the soil in conserving water. In the 19th Report of the New Jersey station, B. D. Halsted presents a varied annual report (80 pp.), similar to those of a number of years back for which he is so justly famous. Among the numerous topics taken up probably the most interesting are "Experiments with asparagus rust" and "Fungi as related to weather." In the 11th Report of the Rhode Island station (1898) H. J. Webber and J. A. Tillinghast present a large amount of interesting data upon the feeding of plants with chemical fertilizers, especially the use of lime on acid soils, the articles being well illustrated. The third part of the 22d Report of the Connecticut station (1898) opens with four articles by Wm. C. Sturgis on diseases of melons, lima beans, tobacco, peach, and use of fungicides. In the 14th Report of the Maine station W. M. Munson has interesting articles on "The blueberry in Maine," "A comparison of large and small radish seed," "The effect of sub-watering radishes," and "Pollination and fertilization of flowers." The botanists of the Vermont station, L. R. Jones and W. A. Orton, give in the 12th Report (1899) a valuable account of potato and apple diseases and their remedies, of killing weeds with chemicals, and of parasitic fungi of Vermont, being the second list.— J. C. ARTHUR.

WE ARE TO HAVE from Dr. Blackman, of the University of Cambridge, a series of papers on the algae, that will aim to give a critical account of the work that has accumulated since Wille's treatment in "Die natürlichen Pflanzenfamilien" of Engler and Prantl in 1890. The first paper[19] has recently appeared, and, excluding the Cyanophyceae, takes up the simpler types of algae, discussing the possible relationships and lines of evolution. The author starts his lines of development from the level of the Protococcoideae, and lays special stress on the Chlamydomonas-like forms, finding in their varied life histories several possibilities of evolution, worked out in different groups of the Chlorophyceae. There are three conspicuous tendencies, resulting in the well-known types of vegetative organization called by him the *volvocine*, *tetrasporine*, and *endosphaerine*.

The volvocine tendency lays emphasis upon the motile phases in the life history, and leads to the specialization and segregation of the ciliated cells in the complex coenobia of the Volvocales. A tendency on the part of resting cells to form filaments, cell plates, and membranes is termed tetrasporine, and results in forms like Tetraspora, Hormidium, etc., and through them leads to the thallus of the Confervales. In the endosphaerine condition vegetative division is reduced to a minimum, and in its place is found the

[19] BLACKMAN, V. H.: The primitive Algae and Flagellata. An account of modern work bearing on the evolution of the Algae. Ann. Bot. **14**: 647. 1900.

peculiar form of multiplication illustrated by Pediastrum and Hydrodictyon. This is essentially a method of spore-formation with the peculiarity that the zoospores, unable to escape from the sporangium, settle down to form a new individual within the mother cell. These three conditions have been recognized by several phycologists, and probably express the history of events fairly correctly for this region of the algae, where the original conditions and later modifying factors seem relatively clear.

The Conjugales, Siphonales, and Diatomales form natural groups that cannot be closely related to the Protococcales or Confervales. They have not been treated in this paper, which deals chiefly with the Chlamydomonas-like organisms, flagellates, and a certain assemblage of forms termed the "Heterokontae." It is doubtful whether most botanists realize that the immense group of the Flagellata resembles the lower Volvocales so closely that no hard and fast line can be drawn between them and the algae. This relationship is treated at some length, and should be welcomed. In his remarks upon the primitive Phaeophyceae Dr. Blackman enters a field of acknowledged difficulty, and while he presents certain possibilities the reader cannot but realize that he is speculating in a region where there is a conspicuous paucity of knowledge.

The author of a paper of this character naturally lays himself open to criticism, for his is an attempt to connect and relate groups as definitely as possible with confessedly fragmentary evidence at hand. Certain difficulties are presented in this paper which cannot be easily overcome. Is not Chlamydomonas much too high a type on which to pivot so many evolutionary lines? What is to be done with the simplest of the Pleurococcaceae? There is little or no real evidence that they are degenerate forms, and this view seems to have its chief *raison d'être* as an assumption to dispose of a troublesome difficulty. Chlamydomonas is very complex as a cell, with its differentiated activities, sex, etc. There were, of course, immense stretches of simpler forms below this level, perhaps rising out of the Cyanophyceae. We know almost nothing of the cytology of the Pleurococcaceae, the Cryptomonadineae, and other border groups. It seems to the writer that we may hope for important results from this field of investigation. We shall probably have to go much farther back than Chlamydomonas before we can hope to clear the maze of relationships in the Pleurococcaceae.— B. M. DAVIS.

OPEN LETTERS.

USE OF FERN NAMES.

WHILE Messrs. Fernald and Pollard are discussing the names by which our American ferns should be known, a few observations upon another side of the subject may be in season. I refer to the practice of fern students in the use of these names. There are in America about two thousand persons at present engaged in the study of our ferns and fern allies. Of this number I am confident that fully nine tenths are committed to what may be called a conservative nomenclature. Granted that the names given in the sixth edition of Professor Underwood's *Our Native Ferns* are correct according to the Rochester code, the mass of fern students see in this no argument for adopting them. The reason why they do not is easily found. In adopting most of the names proposed, the student would be departing from almost world-wide usage and bringing confusion into a part of the study that has thus far practically escaped. A single instance will illustrate. *Cystopteris fragilis* is a plant of almost world-wide distribution. It is found in the West Indies, South Africa, India, and Alaska, as well as the United States, and is everywhere known by the name I have here given it. The question may be fairly asked, then, what it would avail American students to unite with Professor Underwood in calling it *Filix fragilis*. They would only succeed in making themselves misunderstood to fern students in other parts of the world. On the other hand, certain changes, such as Athyrium for part of Asplenium, and Polystichum for part of Aspidium, have been readily adopted, because these names are in common use abroad, and by accepting them the American student comes more into harmony with universal usage. In thus rejecting some names and accepting others, the fern student is really consistent, although at first glance he may not seem to be.

The fact that many of our ferns are common to the old world, also, puts a slightly different aspect on the subject of their nomenclature in the opinion of the student; we cannot "go it alone" in the matter of names. And, after all, those interested in the plants themselves care very little for improvements in their names. At the same time, the value of knowing what names have been proposed for our ferns in the past is not underestimated; these names are a part of the plant's history. But the proposal to adopt them is quite another matter. Just as we have agreed not to go beyond Linnaeus for specific names, although there were such names before his day, so the fern

student prefers not to go back further for his fern names than, say, the fourth edition of Professor Underwood's book or the sixth edition of Gray's *Manual*. In doing this he is essentially adopting the brand of nomenclature advocated by Mr. Fernald, without attempting it.

I am aware that in adhering to certain names regardless of anything but common usage the student is open to the charge of being unscientific, but this does not alter the fact that he does adhere to them. Moreover, by a very few changes in his nomenclature, he can come into harmony with the great majority of students who happen to be following practically the rules suggested by Mr. Fernald, and so avoid being unscientific. The whole question resolves itself into which style of nomenclature will give us stability and uniformity *throughout the world*, with the least change. Some indication of how the tide is setting may be found in the fact that no less than three books on ferns to be issued in the United States this year will use the conservative fern names.—WILLARD N. CLUTE.

NEWS.

DR. WM. BENECKE, privat docent in botany in the University of Kiel, has been appointed to an associate professorship.

DR. B. NEMEC has been appointed Director of the new institute for Plant Physiology of the Imperial Bohemian University of Prag.

ACCORDING to *Science*, the extensive herbarium of the late Dr. T. Bernard Brinton has been presented to the Botanical Garden of the University of Pennsylvania.

EDWARD W. BERRY a member of the Torrey Botanical Club has been awarded the Walker prize of fifty dollars by the Boston Society of Natural History for a memoir on Liriodendron.

THE TRANSFER of the late Dr. J. G. Agardh's herbarium of algae to the University of Lund is made on the express condition that no specimens be loaned. While this will doubtless tend to preserve a valuable collection of types, it seriously restricts its usefulness.

A RECENT NUMBER of *Plant World* announces that the herbarium of the veteran collector, Mr. A. H. Curtiss, containing about 16,000 sheets, was destroyed in the recent great fire at Jacksonville, Florida. His early collections for this year's distribution were saved.

A SUMMER SCHOOL for nature study is to be held at the Rhode Island College of Agriculture and Mechanic Arts, Kingston, from July 5th to 20th. A course on trees and garden plants will be given by Professor Fred W. Card and Mr. George E. Adams; on flowering plants by Professors W. W. Bailey and H. L. Merrow; on seaweeds and fungi by Dr. A. B. Seymour.

IT IS WITH great regret that the BOTANICAL GAZETTE records the death of Professor Thomas Conrad Porter of Easton, Pa. He died April 27, 1901, at the age of seventy-nine. Since 1866 he has been identified with Lafayette College, and has long been one of the best known American taxonomists. A biographical sketch will be published in an early number of the GAZETTE.

THE BIOLOGICAL station of the University of Montana, established in 1899 on Flathead lake, will be opened this year on July 22. The University supplies books, chemicals, glassware and microscopes for use free; students are charged only for material used and breakage. The botanical work will be in charge of Dr. D. T. MacDougal and Mr. R. S. Williams, of the New York Botanical Garden.

GENERAL INDEX.

The most important classified entries will be found under Contributors, Personals, and Reviews. New names and names of new genera, species, and varieties, are printed in **bold-face type**; synonyms in *italics*.

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